MODERN BUILDINGS THEIR PLANNING CONSTRUCTION & EQUIPMENT

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MODERN BUILDINGS

THEIR PLANNING, CONSTRUCTION AND EQUIPMENT

BY

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VOL. III

PART I. SCHOOL AND HOSPITAL PLANNING
PART II. THE LAW OF EASEMENTS
PART III. HEATING, VENTILATING, AND LIGHTING

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LIST OF CONTENTS TO VOLUME III

PART I

SCHOOL AND HOSPITAL PLANNING

CHAPTER I

PAGE

Regulations Applicable to School Planning 1

CHAPTER II

Small Elementary Schools 7

CHAPTER III

Large Elementary Schools 12

CHAPTER IV

Higher Grade and Technical Schools 19

CHAPTER V

Private and Special Schools 24

CHAPTER VI

Hospitals on Open Sites 28

CHAPTER VII

Hospitals on Restricted Sites 39

CHAPTER VIII

Small and Special Hospitals 49

PART II

THE LAW OF EASEMENTS

CHAPTER I

The Principles of Easements—Light and Air 54

CHAPTER II

Light: Nature of the Right 58

CHAPTER III

PAGE

Light: Acquisition of the Right 63

CHAPTER IV

Light: Disturbance, Remedies, and Extinction 68

CHAPTER V

Air 71

CHAPTER VI

Support 74

PART III

HEATING, VENTILATING, AND LIGHTING

CHAPTER I

The Principles of Hot-water Apparatus 79

CHAPTER II

Domestic Hot-water Supply—General Principles 82

CHAPTER III

Domestic Hot-water Apparatus—the Tank System 84

CHAPTER IV

Domestic Hot-water Apparatus—the Cylinder and Cylinder-tank Systems 88

CHAPTER V

Hot-water Heating Works—Low Pressure 91

CHAPTER VI

Hot-water Heating Works—High Pressure 104

CHAPTER VII

Steam-heating Apparatus 109

CHAPTER VIII

Ventilation: with which is included Warming Buildings by Heated Air 119

CHAPTER IX

PAGE

Grates and Stoves (for Coal Fuel) 134

CHAPTER X

Gas-fitting 144

CHAPTER XI

Gas Lighting and Heating 147

CHAPTER XII

Acetylene Lighting 152

CHAPTER XIII

A Comparison between Gas and Electric Lighting 159

CHAPTER XIV

Simple Magnetic and Electric Phenomena 162

CHAPTER XV

Units used in Electrical Measurements 166

CHAPTER XVI

Wires and Cables—Jointing 168

CHAPTER XVII

Arrangement of Cables and Cut-outs in a Building 171

CHAPTER XVIII

Casing and Conduits 181

CHAPTER XIX

Electrical Accessories, Fixing and Connecting 183

CHAPTER XX

Private Installations 192

CHAPTER XXI

Electric Lighting Regulations 194

CHAPTER XXII

Oil Gas 198

LIST OF COLOURED AND HALF-TONE PLATES IN VOL. III

Plate	I.	Day School for Girls	*Facing page* 24
,,	II.	British Hospital, Constantinople	,, 48
,,	III.	Linslade Cottage Hospital, Leighton Buzzard	,, 49
,,	IV.	Woburn Cottage Hospital	,, 52
,,	V.	Cylinder Tank and Cylinder System with Secondary Circulation, Hot-water Apparatus	,, 88
,,	VI.	Electric Lighting Installation to a Small School	,, 176

MODERN BUILDINGS

VOLUME III

PART I

SCHOOL AND HOSPITAL PLANNING

CHAPTER I

REGULATIONS APPLICABLE TO SCHOOL PLANNING

As a result of many years of close and specialised study, the planning of all schools which depend for their maintenance in any way upon grants from public funds has been reduced to an exact science, epitomised in a series of regulations made by the Board of Education. These it is proposed to give in a condensed form, the permission to do so having been obtained of the Controller of His Majesty's Stationery Office. They are consequently authentic, but it would always be advisable to consult the official publication, in case of changes having been made, or of accidental misconstructions here.

It will be found that these regulations are framed with wise elasticity, yet they have led to the development of recognised types of schools, admirably suited for teaching purposes, which will be more fully described in later chapters.

General Principles

The main requirements to be considered in planning are the number of boys and girls for whom provision is necessary, while the distribution of scholars in respect of age has also an important bearing on organisation. The type of building will probably depend to some extent on the manner in which the Local Education Authority have acted in excluding children under five years of age. The nature of accommodation required in upper departments of ordinary schools will be affected if higher elementary schools are already provided in the locality.

A head teacher can seldom effectively undertake responsibility for more than four to five hundred scholars, in addition to the staff required for that number. This is therefore the greatest number for whom provision can wisely be made in one department. Each department must have its own head teacher, responsible for general control, supervision, instruction, and discipline.

The number of departments on any site will depend on the total number that provision is required for. It will seldom be that more than three departments (or four, if one be for boys and girls of from seven to nine or ten years of age) could properly occupy parts of the same building. When a school with separate departments for boys, girls, and infants is attended by all children of the area for which it is available, it is not unusual to find the average attendance in each department much the same. It is desirable to have a certain margin of places in the infants department to meet greater variability of attendance at different seasons. These considerations should be kept in mind in deciding how many places shall be provided in the several departments of a large school; in every case local circumstances must be carefully considered.

The number and circumstances of the scholars attending each department, and the number and qualifications of the staff employed in each, determines approximately the grouping of scholars, the number of rooms to be provided, and the places in each. Rooms must be grouped compactly and conveniently to secure

proper organisation and supervision. Every public elementary school must be planned so that children who attend can be seated in the best manner. The places provided in any room depends not only on area, but also on lighting, shape of room (especially in relation to kinds of desk proposed), and position of doors and fireplaces, which should be so arranged as to allow the whole of one side to be left free for groups of desks.

For large departments containing from 350 to 500 places the most suitable plan is that of a central hall with rooms grouped round it. Such a department would require seven to ten classrooms.

Smaller departments may be conveniently planned with classrooms opening from a corridor, and this arrangement may even be adopted for larger departments. For small schools a schoolroom with one or two or more classrooms is sufficient. There should be at least one classroom

Where a site is sufficiently large and open, the most economical and preferable plan is to have all rooms on the ground floor. It is desirable in any case that a school should not be more than two floors in height. A three-floor building is open to many objections, though necessary in special circumstances; for example, where land is costly, or where it is otherwise impossible to obtain adequate area for playgrounds.

Central Halls

When there is a *Central Hall* it should have floor space of not more than 4 square feet for each scholar, while about $3\frac{1}{2}$ will really be sufficient. The hall must be fully lighted, warmed, and ventilated.

A single central hall may be provided for use at separate times by two departments, so long as it be so placed as to be readily accessible from the classrooms of each.

Where outdoor space is unavailable, physical training should be given in the hall (or corridor). This should be taken into consideration when planning. Gymnastic apparatus being unsuitable for children under 14, a separate gymnasium cannot be approved.

Corridors

Large Schools not having a central hall must be provided with a wide corridor giving access to the rooms, two or three of which should be divided by movable partitions, so that one large room may be available. A corridor should be fully and directly lighted and ventilated, and from 8 to 12 feet wide according to size of school.

Schoolrooms

When a *Schoolroom* is the principal room in a school with neither hall nor corridor, it should never be designed for more than 100. A room of even smaller size is desirable. Width should vary according to kind and arrangement of desks.

No schoolroom lighted from one side only can be approved. Gable ends should be fully utilised for windows, but there should be no superfluous windows opposite the teacher.

A school consisting of a single room should not contain more than 600 square feet of floor space.

Classrooms

The number of *Classrooms* should be sufficient for the requirements of the school. Classrooms should not be passage rooms from one part of building to another, or from schoolrooms to playgrounds or yard. Schoolrooms and classrooms must have independent entrances, and rooms should be so arranged that each can be easily cleared without disturbing work in another.

A classroom should not be planned for more than 50 or 60 children (in special cases larger rooms may be approved), and not less than 24 scholars. In absence of supplementary light, measurement from window wall in a room 14 feet high should not exceed 24 feet 8 inches.

Proportions of classrooms vary with kind and arrangement of desks. A long narrow room should be avoided, while a room approximately square is most satisfactory.

Desks

Seats (fitted with backs) and desks should be provided, graduated according to children's ages, and placed at right angles to window wall. Eighteen inches per scholar at each desk and seat in determining lengths of same is sufficient with gangways 18 inches wide between groups and walls. In case of dual desks, the usual length is 3 feet 4 inches with gangways 1 foot 4 inches. In an ordinary classroom five rows of long desks or six of dual are best. A room providing for more than 60 children should not have more than four rows of long or five of dual desks. Long desks should be arranged that a teacher can pass between the rows. With dual desks this is unnecessary, as gangways give sufficient access. A teacher should be able to pass behind back row. Desks should be very slightly inclined. An angle of 15 degrees is sufficient. A flat desk has a tendency to make children stoop. A raised ledge in front interferes with the arm in writing, and the edge when used for writing should be vertically over the edge of seat.

Accommodation

Accommodation in any school—*i.e.* number of places for which it is finally recognised—depends in part on arrangement of desks, which must be approved by the Board of Education. The central hall, corridor, and classrooms for cookery, laundry, handicrafts, drawing, or science are counted toward accommodation. When a building is for use of older scholars, plans of school and classrooms must show average of not less than 10 feet square of floor space for each place provided.

Infants' Schools

Infants should not, except in very small schools, be taught in same room with older children. Access to

infants' room should never be through a senior school-room.

Partitions between infants' and any other rooms should be impervious to sound, and there should be no means of communication other than an ordinary door. Both school and playground should always be on ground floor. No classroom should, as a rule, accommodate more than 60. Space in which children can march and exercise should be provided. Corridors for this purpose should not be less than 12 feet wide.

A *Babies' Room*, where provided, should always have an open fireplace.

An allowance of 16 inches per child at long desks is sufficient, or dual desks 3 feet long. When a building is wholly for the use of infants, plans must show an average of not less than 9 square feet for each place provided. If an *Infants' Room* be attached to a school for older children with no corridor or hall provided, the classroom should have a larger floor space than 9 square feet per child. Provision should be made for sufficient space free of desks for exercise, and it should extend across the room for a width of not less than 12 feet.

Cookery Room, etc.

As a rule, a room for cookery, laundry, handicraft, science, or drawing will serve more than one school when it is provided, as a centre, in a convenient position. Every centre should have its cloakroom and lavatory.

A *Cookery Centre* should accommodate 12 to 18 at practice, or 36 to 54 at demonstration. The larger size requires 750 superficial and 10,500 cubic feet. Provision for scullery work is necessary, and the sink should be in full view of teacher and children.

A *Gallery or Platform* with desks should be provided for 36 to 54, according to size of room. Floor space for practical work should be about 20 square feet for each, exclusive of any encumbrance.

Cookery Room Ventilation requires special arrangements. Where a gas stove is used, a pipe should be fixed to carry off fumes.

Laundry Centres

Laundry Centres should be simple in construction, entirely apart from ordinary school buildings, comprising about 750 square feet, and should have gallery or platform with desks for 42. Laundry tables, with at least 3 feet allowance per child, should also be provided. Ventilation requires special attention for removal of steam.

Handicraft Room

The arrangements, construction, lighting, and ventilation of a *Handicraft Room* should be modelled on a practical workshop rather than a school. The construction should be simple. The height at windows in front of benches need not be more than 10 feet, but ample light must be provided, and a flat ceiling is not necessary. Ample ventilation should be provided by inlets 5 feet from floor and outlets at highest point. Twenty scholars should have floor space of about 700 square feet.

Science Room

This room, when required, should not, as a rule, contain more than 600 square feet of floor space. It should be suitably fitted for instruction, and a fume closet provided if necessary in addition. An ordinary classroom may have a suitably fitted demonstration table. Special lecture-rooms are unnecessary in an ordinary elementary school.

Drawing Classroom

This room, where sanctioned, should have about 600 square feet of floor space, and light admitted at a suitable height and angle from north, north-east, or east.

Higher Elementary Schools

A Higher Elementary School should, in general, be planned in accordance with the principles already described, as applied to ordinary public schools. Such a school for 300 to 350 scholars would usually require 8 to 10 classrooms, since every class should have its own room, no room accommodating more than 40. Rooms may be furnished by single or dual desks as desired. If single, a room should have area of about 15 square feet per scholar. If with dual desks, allow a minimum of about 12 square feet per scholar. If *Cookery*, *Laundry*, *or Handicraft* be taught, a room should be provided in accordance with the rules previously given for same.

If *Advanced Drawing* is taught, a separate room is desirable, and should provide 30 square feet of floor space for each person using it at any one time. If the school has a suitably lighted central hall, it would answer this purpose, but no other than a drawing class should be held in a central hall.

A *Laboratory* (if included) should afford the same floor space as above, must have suitable tables, well lighted, and fitted as required for experimental work. If it be used for Chemistry it should have sinks, cupboards, and the necessary fume closet.

Should there be a separate lecture-room where Chemistry also is taught it should be fitted as above; or one or more classrooms may be fitted as above instead of providing a separate lecture-room. A small preparation-room may be provided near a lecture or other room used for this purpose in schools where Science is taught.

Teachers' Room

A large school should provide, for the use of teachers, a small room or rooms, with a store for books and other material adjoining, and suitable lavatory accommodation, etc.

Teachers' House

When provided, this should contain parlour, kitchen, scullery, and three bedrooms, the smallest dimensions approved being:—

	Feet.	Feet.
Parlour	14 by 12	by 9 to ceiling or wall-plate
Kitchen	12 by 12	by 9 do. do.
1 Bedroom	14 by 12	by 8 if ceiled at wall-plate, or
2 Bedrooms	12 by 8	7 feet to wall-plate and 9 feet to ceiling.

The residence must be planned so that no room is a passage room and no chimneys are on external walls, and with no internal communication between residence and school. The windows should be carried up as near ceiling as practicable, and there should be a separate and distinct yard with offices. No dwelling house should be built as part of the schoolhouse.

Hygienic and Sanitary Conditions, Construction, and Emergency Rules

Site and Playground.—In planning a school the playground should be open and airy, proportioned to size and need. The site should, if possible, have a building frontage suitable to its area.

A site open to the sun is specially valuable to children, and important in effects on ventilation and health. The minimum size of site in absence of exceptional circumstances is a quarter acre for every 250 children irrespective of space for teacher's or caretaker's house, and cookery or other centre. If the school is of more than one storey the area may be proportionately reduced, but a minimum open space of 30 square feet per child should be preserved.

Except in case of very small schools, boys' and girls' playgrounds are separate, having, where practicable, separate entrances from the road. All playgrounds should be fairly square, levelled, drained, and enclosed. A portion should be covered, and have one side against a boundary wall. A covered way should never connect offices with main building, while buttresses, corners, and recesses should be avoided. Infants' schools should have the playground on same level as school. A sunny aspect is of importance.

Walls, Floors, and Roofs

The Height of Rooms for teaching, if ceiled at level of wall-plate, must be at least 12 ft. from floor to ceiling; if area of room exceed 360 sq. ft., 13 ft. in height; if 600 sq. ft., it must at least be 14 ft. high.

Height of rooms for teaching, if ceiled to rafters and collar beam, must be at least 12 ft. from floor to wall-plate and 14 ft. to the ceiling at collar. Great care should be taken to render roofs impervious to cold and heat. Those open at apex are very undesirable, and are permitted only where roofs are specially impervious to heat and cold, and where apex ventilation alone is provided.

In case of a school of more than one storey, care must be taken to render floors sound-proof.

The whole of external walls of school and residence should be solid. The thickness must be at least one brick and a half, or 20 inches if of stone. Where hollow walls are proposed, the external leaf must be 9 inches thick, with a $4\frac{1}{2}$ feet lining and a 2-inch cavity between.

The erection of schools lighter in construction—namely, of iron, wood, or other suitable material—is only sanctioned in very special circumstances, as, for example, in colliery districts where, owing to mining operations, no site is available for a building of the ordinary solid type to be safely erected; or where population is not of a stationary nature, as during the progress of a large engineering work, or when temporary accommodation is required during the re-building of an old school or the building of a new one.

Where such buildings are proposed, special care must be taken to ensure the comfort of children regarding warmth and ventilation. All walls should have a damp-proof course just above ground level. The whole space within the area of a building should be covered with a layer of concrete not less than 6 inches thick, and air bricks should be inserted in opposite walls to ensure a through current of air under floors, whilst timber should be protected from mortar and cement by asphalt or tar.

Entrances

These should be separate for each department and sex. In large schools more than one to each department is desirable. Entrance doors should open outwards as well as inwards. A porch should be external to a schoolroom, and a door having outside steps requires a landing between the door and threshold.

Staircases

Separate Staircases are necessary for boys and girls, and each department should have its own. They must be fireproof, external to halls, corridors, or rooms, and winders must not be used. Each step should be about 13 inches broad and not more than $5\frac{1}{2}$ to 6 inches high; flights should be short, and landings unbroken with steps. The number of staircases must be sufficient not only for daily use, but for rapid exit in case of fire or panic. Any upper floor for more than 250 requires a second staircase.

Cloakrooms and Lavatories

Cloakrooms should not be passages, should be external to school and classrooms, lighted from end, and not placed against a gable wall, which should be fully utilised for windows to give light in rooms for teaching. There should be separate egress and ingress, so that the children can enter and leave without

crowding, with gangways at least 4 feet between hanging rails. Hat-pegs should be 12 inches apart, numbered, and of two tiers, and not directly one above the other.

Lavatory basins are required, with a larger number in girls' schools than for boys or infants. A lock-up slop sink, water tap, and cupboard is desirable for the caretaker's use.

Thorough ventilation and disconnection are essential, so that no smell is carried into the school. Ample space is needed outside a cloakroom.

Lighting

Every part and corner should be well lighted, and, so far as possible, especially in classrooms, the light should be admitted from left side of scholars. Other windows in classrooms should be regarded as supplementary or for ventilation. Right-hand light is best where left is impossible. Windows full in the eyes of scholars cannot be approved. Unless the tops of windows are more than 14 feet above floor, the plan should show no space for teaching more than 24 feet from window wall of any room.

Windows should never be provided merely for external effect, and glazing which diminishes light and is a trouble to keep clean or in repair must be avoided. A large portion of each should open for ventilation and cleaning. Sills of main lighting windows should not be more than 4 feet from floor; and the tops of windows should, as a rule, reach nearly to ceiling, the upper portion being made to swing. Ordinary rules respecting hospitals should be remembered. Large spaces between window heads and ceilings are productive of foul rooms.

Skylights are objectionable, and not approved in school or classrooms. They are only allowed in central halls having ridge or apex ventilation. The colour of walls, ceilings, and all fittings in rooms should be carefully considered as affecting light; while the size and position of windows are especially important in bearing on the eyesight.

Windows should be properly distributed over walls of classrooms, so that every desk shall be sufficiently lighted. The glass line of the window farthest from the teacher should be on a line with the back of last row of desks.

Ventilation

There must be ample provision for continuous inflow of fresh air and outflow of foul. The best way of providing this is to build to each room separate air flues, carried up in the smoke stack. An outlet should be formed by a warm flue or exhaust, otherwise it acts as a cold inlet. Inlets are best in corners farthest from doors and fireplaces, and should be made to discharge upwards. Gratings in floors should never be used. Outlets in ceilings must not open in a false roof, but must be properly connected with an extract ventilator. The size of inlets and outlets must be adapted to method of ventilation proposed. A much larger area is required when no motive force is provided. Windows should have top and bottom panes arranged to open inward as hoppers. Besides being continuously ventilated by above means, rooms should, as often as possible, be flushed with fresh air through all windows and doors, fully opened. Sunshine is of particular importance in its effects on ventilation and health.

Ventilation also demands provision of a small swing window, as far from the lighting as possible, and near the ceiling.

Warming

Sufficient provision for heating, evenly distributed, must be made. When a corridor or lobby is warmed, rooms are more evenly dealt with and less liable to cold draughts. If a school be wholly warmed by hot water, radiators are recommended. Fireplaces in addition are useful for extra warming, and the flues for ventilation. A stove with pipe through wall or roof can under no circumstances be permitted, and is only approved when provided with proper chimney, or of such pattern that it cannot become red hot or otherwise contaminate the air. It must be supplied with fresh air direct, by a flue not less than 72 inches super., and not of a size or shape to interfere with the necessary floor space for teaching. Fireplaces, where used, are best in corners, to leave space for a teacher's desk, blackboard, etc.

Sanitation

W.c.'s in the main buildings are undesirable, and only required for female teachers. All others should be completely disconnected, and privies should be fully 20 feet away.

Latrines and approaches must be wholly separate for boys and girls. In the case of mixed schools this specially affects planning. Neither should boys and girls use the same passages or corridors. If absolutely unavoidable, complete supervision from classrooms by glass windows must be made.

W.c.'s must be not less than 2 feet 3 inches in width, or more than 3 feet, fully lighted, ventilated, and supplied with doors, which should at least be 3 inches short at bottom and 6 inches at top.

Children must not be obliged to pass in front of a teacher's residence to reach latrines.

The following table gives the approximate number of closets:—

	Girls.	Boys.	Infants.	Girls and Infants.
Under 30 children	2	1	2	2
,, 50 ,,	3	2	3	3
,, 70 ,,	4	2	3	4
,, 100 ,,	5	3	4	5
,, 150 ,,	6	3	5	6
,, 200 ,,	8	4	6	7
,, 300 ,,	12	5	8	8

Urinals must be provided in the proportion of 10 feet per 100 boys (also for infant boys). If the numbers

in a school are not large, offices common to girls and infants can be provided. A proper proportion of closets must then be of a suitable height for infants.

E.c.'s of approved type may be used in rural districts, but drains for the disposal of surface and slop water are necessary.

Cesspits and privies should only be used where unavoidable, and should be placed at a distance of at least 20 feet from school.

Soil Drains must be outside building (on a hard even bottom of concrete), laid in straight lines of glazed stoneware pipes carefully jointed in cement, absolutely water-tight. A diameter of 4 inches is sufficient unless receiving discharge of more than 10 closets ; then it should be 6 inches. The falls should not be less than 1 in 30 for 4 inch and 1 in 40 for 6-inch drains. Inspection chambers should be provided at each change of direction. Every soil drain must be disconnected from main sewer by properly constructed trap placed on line of drain between latrines and sewer. This drain must be thoroughly ventilated by at least two untrapped openings ; one being the 4-inch soil pipe carried up full size above roof, and the other an inlet pipe connected with side of the trap farthest from public sewer. Automatic flushing tanks are best where trough closets are used.

Waste Pipes from sinks and lavatories should be first trapped inside and then discharged direct through outer wall over trapped gully.

Water Supply

In all schools adequate and wholesome drinking water must be available for scholars.

In cases where it is not taken from the mains of an authorised company, care must be taken to ascertain that it is both adequate in quantity and of suitable character, and not liable to pollution in any way by surface drainage, leakage from sewers, drains, cesspools, or other receptacles. Water pipes should be properly protected from frost, and laid in such positions that, in the event of their becoming unsound, the water will not be liable to foul or escape without observation.

There should be no communication between any pipe or cistern from which water is drawn for domestic purposes and any w.c. or urinal. Any cistern used for water storage should be properly covered, ventilated, and placed in such a position that it may be readily inspected and cleansed.

CHAPTER II

SMALL ELEMENTARY SCHOOLS

School planning is a branch of an architect's work to which a very large amount of attention has been given during the last half century, and at the present time elaborate regulations exist upon the matter, smaller schools being planned as a general rule on the *Corridor System*, and larger schools on the *Hall System*. The division between small and large schools is generally drawn at about 300 scholars.

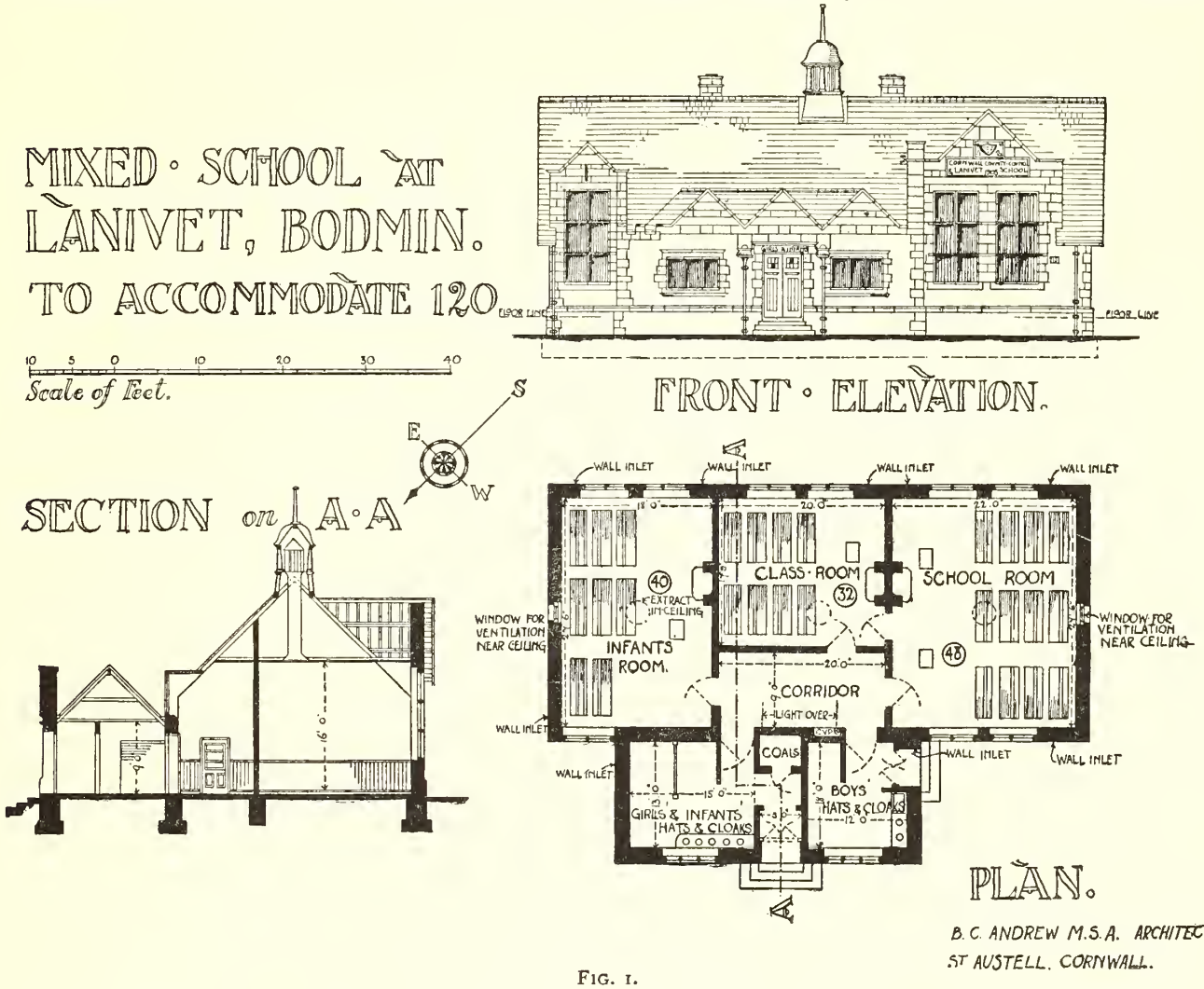


Fig. 1.

drawn up by the Board of Education, as epitomised in the last chapter. With these it is always necessary to comply in cases of schools which are in any way supported by public funds, and although it is possible to do so in many different ways, yet the fact of the existence of the regulations has gradually led to the development of certain distinct types of plan. Of these there are two which are in general use, It is usual to divide a school into separate departments for boys, girls, and infants, the smaller schools as a rule having these departments in separate buildings, except that the infants are often found in close attachment to the girls, it being permissible to consider "girls" and "infants" as a single department. Where more than one department exists in the same building they are kept perfectly distinct, with different

entrances and exits, and different playgrounds, mixing only in the general schoolroom in quite small schools.

A school of almost the smallest type is that designed by Mr. B. C. Andrew for Lanivet, near Bodmin (see Fig. 1). This is planned as a mixed school for 120 scholars, and is upon the corridor system. There is a separate entrance for boys, and a combined entrance for girls and infants, in each case through a lobby out of which a cloakroom opens with a few lavatory basins in it. Admission is given from the entrance lobby to a top-lighted corridor, and from this three rooms are entered, one being the general schoolroom, one a classroom, and the other an infants' room. Boys and girls are taught together in all three rooms, and provision is made for four teachers in all. It will be noticed that the regulations have been carefully complied with, and the school is so placed that sunlight enters all the rooms during the morning hours, for all have windows to the south-east. The schoolroom and infants' room also have windows to the north-west, besides smaller windows for ventilation near the ceiling on their longer sides. These, however, are not taken into account for lighting the desks, all of which are so placed as to be lit from either left or right hand, and generally from the left. In each case, too, there is, behind the teacher's desk, a blank piece of wall, on which a blackboard can be fixed in such a position that it would be well lighted and could be seen by all the pupils. The schoolroom and classroom communicate, but the infants' room, in accordance with regulations, is entirely distinct, so that no noise could penetrate from it to either of the other rooms. As each room opens into the corridor there is no need for the students to pass through one room to reach another, this being expressly forbidden. The spacing of the desks, with passage ways, and gangways between the rows, enables the work of every child to be properly supervised, and it is usual for the desks to be placed upon platforms, the front row only being on the floor level, and the back rows gradually rising a step at a time.

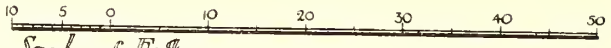
In a small school of this sort there would be no special system of ventilation, save by ordinary air inlets and an exhaust in the roof, while heating would be by means of ordinary fires.

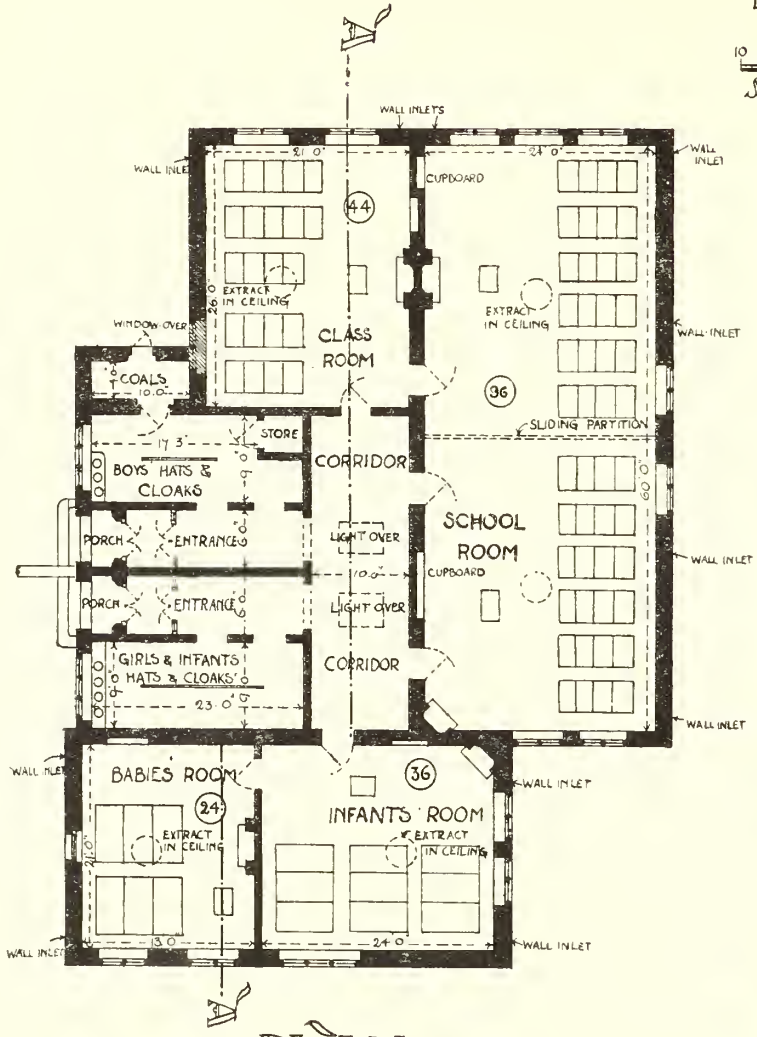
It will be noticed that the outline of the plan is one of perfect simplicity, and that, while the eaves are kept low, sufficient height for the windows is obtained by means of dormers. The position of the coal store and the provision of a cupboard may be noticed as minor conveniences, while the entrances, though narrow, are so contrived that no draught enters. The corridor of the school is thereby kept warm in winter time.

A somewhat larger school, to accommodate 200 students, is that at St. Denis (see Fig. 2), designed by the same architect, again as a mixed school for boys, girls, and infants. In this case the schoolroom has accommodation for no less than 96 pupils. It is divisible into two for teaching purposes by means of a sliding partition. As one result of this the corridor is of greater length than at Lanivet, and better arrangement of the cloakroom has been possible, the entrance being without turn from porch to corridor, while there are two doorways without doors to each of the cloakrooms. The coals are again reached under cover, but in this case open out of the boys' cloakroom, from which a small piece has also been taken as a store. The schoolroom is 60 feet long and is lighted on three sides, so that some of the desks are necessarily back lighted. As in the previous case, both this and the classroom are intended to accommodate boys and girls, but there is a difference in the arrangement of the infants' room, which has a babies' room opening out of it. This is permissible, as the two are considered to belong to one another, though it is against the strict letter of the regulations that any room should be a passage room to any other. The corridor is top lighted, and is 10 feet wide. The elevation shows that the building is to be erected on a hillside, but in spite of this the floor has been kept quite level, and consequently lies below the ground at the upper part of the hill; and of course it is necessary to make special provision in such a case against the penetration of damp. In both these examples it has been possible to plan with extreme simplicity and directness, and to provide plenty of light to every room, so that it falls as a general rule in the best direction on to the desks. The principal windows give side lighting in each case, though supplementary lighting is at times obtained behind the backs of the pupils, not only in the schoolroom, as already referred to, but in all the other rooms also.

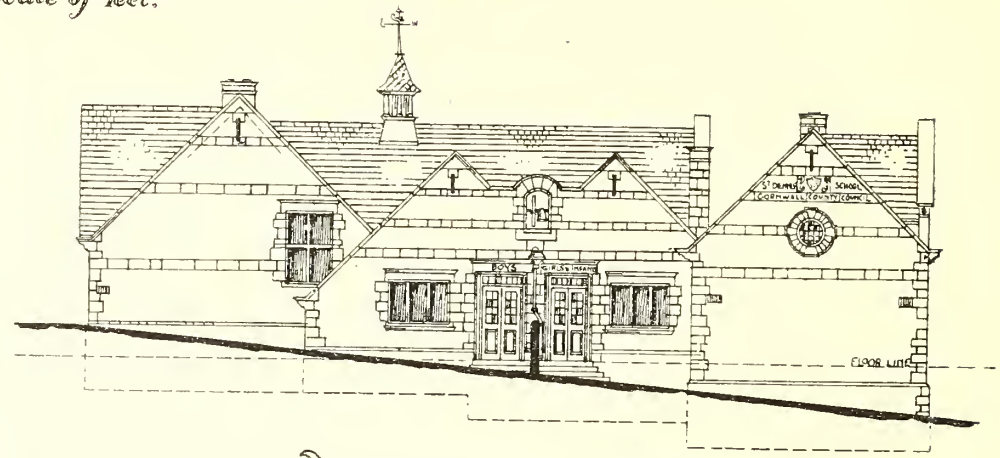
It is, as a general rule, much more difficult to alter an old school satisfactorily than to build a new one. A problem of this description is shown in Fig. 3, the plan on the left-hand side representing a school for girls and infants in connection with Holy Trinity Church, Upper Tooting, as it was in the early part of 1903. This school had not been built all at one time, but had gradually grown to its present proportions by the addition of small pieces here and there. There were two entrances in the front, opening directly into classrooms, which were passage rooms from one to another in series, until a cloakroom was reached in the form of a low and dilapidated shed in a yard at the back; while the infants, as a general rule, passed down an open passage beside the mistress' house into a playground, and came in through their cloakroom under a covered way. A little examination of the plan will show that a great number of the regulations were in abeyance. The cloakroom accommodation was insufficient, the rooms were passage rooms, and the lighting was in many instances bad, while the entrances were not under good supervision. At that time the Borough Council wished to widen the road in front to such an extent as to cut away

MIXED SCHOOL AT ST. DENNIS.
TO ACCOMODATE 200.

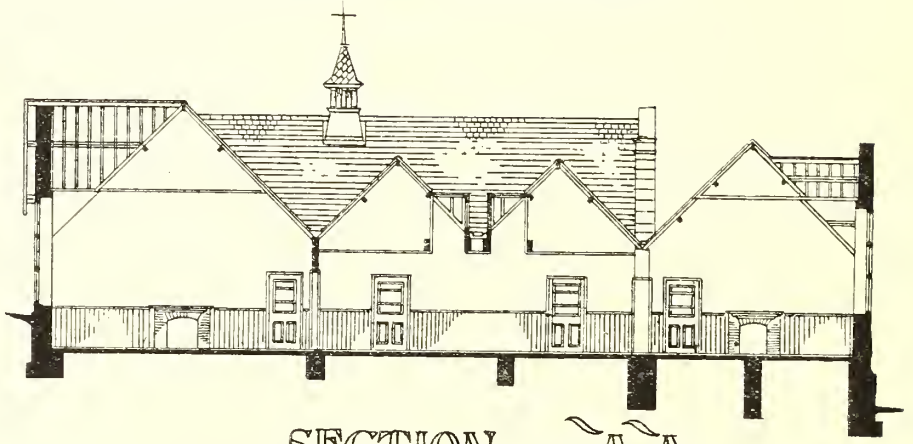




PLAN.



ELEVATION TO ROAD.



SECTION on A·A

B.C. ANDREW M.S.A.
ST AUSTELL.
CORNWALL.

FIG. 2.

the entrance porches, and the opportunity was taken to thoroughly revise the plan. It was decided that for the future the entrances should be made entirely from the playground in the rear, except for a supplementary or emergency exit for girls in the front. The yard was utilised, the existing cloakrooms swept away, and a piece of the infants' classroom cut off to form a direct passage way to some of the rooms. By this means the school was divided into two sections, each having a separate entrance and corridor leading to its various rooms. Every room was now served from a corridor, and ceased to be a passage room, and plenty

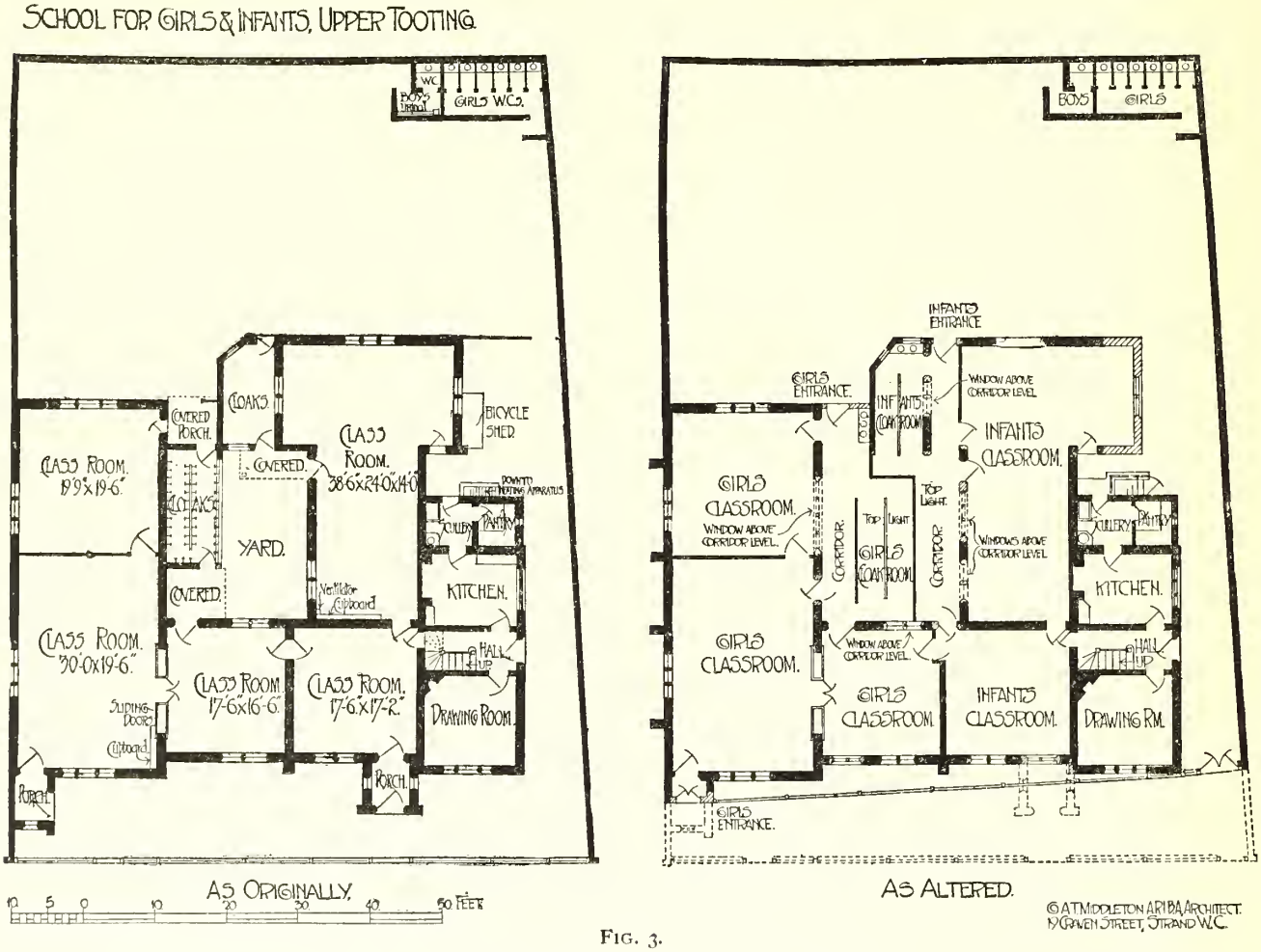


FIG. 3.

of cloakroom accommodation was provided, both for the girls and for the infants. In order to retain the same seating accommodation as before, however, it was necessary to pull down one of the end walls of the infants' classroom, and to extend the room so as to make up for the piece which had been cut away from it to serve as a corridor—even though the portion cut away was merely enclosed in a boarded partition and ceiling, so as still to admit light to the classroom from the window which opened above the cloakroom level. Several similar windows at high levels were added, the cloakrooms and corridors being kept quite low and flat roofed to enable this to be done, thus adding light to every one of the rooms, either by this means or by additional windows opening in front. The final result of all this was to convert a remarkably unsatisfactory school into a satisfactory one, complying with the regulations in almost every detail—at anyrate so far as the school itself was concerned, though the mistress' house remains small, and there is direct means of communication between it and the school by means of a door, which is generally kept locked. The cloakrooms, it may be mentioned, as well as the infants' corridor, are top lighted and ventilated. It will be noticed that there are no fireplaces shown in any of the classrooms, as the heating is accomplished entirely by hot water, the boiler for which is in a basement; and it will also be noticed that there is no general schoolroom, the whole of the work being done in classrooms. This, however, is no detriment. Girls and infants are taught entirely separately, and the only means of communication between the two departments is through a single door entirely under the mistress' control.

The large L-shaped infants' classroom has, since this plan was prepared, been divided into two by means of a

glass partition placed where the word "Classroom" is printed, and an additional window has been inserted.

The example is given in order to show by what simple means it is often possible to convert a bad into a good school, if care be taken in the matter. In this case the alterations were necessitated by the widening of the road, but in many others similar changes have been called for on the recent transference of what are called "non-provided" schools to partial control by the Local Authority. The example will serve also to emphasise the immense advance which has taken place in the planning of small schools since the subject first came into prominent notice, everything being now done by regulation and rule according to ascertained best methods, whereas formerly all was experiment upon lines which were little understood.

It may be noticed that considerable use is made of top lighting in all these cases, this being possible and even advantageous with schools which are of only one storey in height. Attention has already been drawn to the lighting of the classrooms in the Upper Tooting schools by means of windows which are at a sufficiently high level to obtain their light above the low flat roofs of the cloakrooms, while the cloakrooms themselves have top lights in the form of lanterns, the sides of which consist of open louvres for ventilation. It is somewhat in the same way that the corridors of the other schools have been lighted. Naturally this cannot be done with schools which are built with one floor over another, but there is no reason at all why advantage should not be taken of the opportunity, when it occurs, of lighting and ventilating in this way. It is generally considered preferable, however, that a small school should be on one floor only, unless the site is so restricted that if this were done there would be insufficient playground area, which is hardly likely in the small rural districts where most small schools are built.

CHAPTER III

LARGE ELEMENTARY SCHOOLS

Just as the smaller elementary schools are almost invariably devised upon the "Corridor" system, so are the larger schools planned on the "Central Hall" system. The idea is that there are times when it is advisable to collect all the scholars into one hall for special announcements, while it is also more convenient than is a narrow corridor when there are a large number of scholars passing in and out

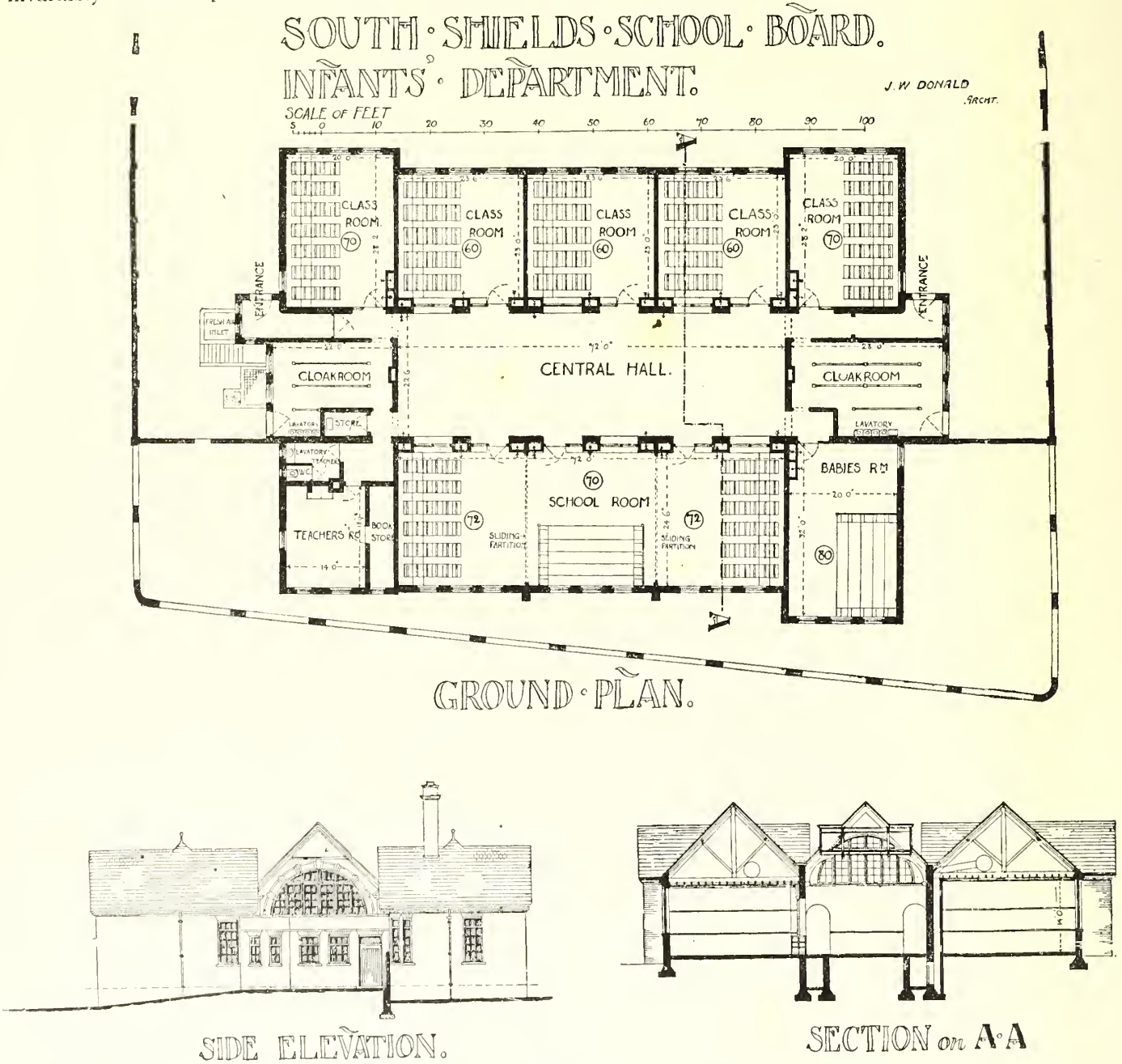


Fig. 4.

between classrooms and playground at the same moment.

When the school is only one storey in height, as in the large infants' school at South Shields (see Fig. 4) designed by Mr. J. W. Donald, A.R.I.B.A., the hall is generally placed in the centre of the building with the classrooms on both sides, it being best if the hall runs nearly due north and south, so that the classroom windows face to either east or west. In this particular school, although it is for infants only, there are two entrances, one at either end, there being a single turn in each, and also an inner door for prevention of draught. Before the hall is reached there occurs a large cloakroom, which also has an external door into the playground and can be traversed either diagonally or across one end, so that with a little organisation the children can be made to pass in and through and not to return by the way in which they entered. (A similar arrangement will be noticed in both the new cloakrooms shown in Fig. 3.) A little point like this is sometimes of considerable value, as, if overlooked in the planning, it is impossible afterwards to prevent crushing and inconvenience. There is one classroom at each end which opens out of the entrance corridor, while corresponding to one of these is the babies' room, with rapid exit through the cloakroom to the playground. Corresponding with the other similar classroom there is a teachers' room and book-store under the teachers control, while a general store-room is obtained by taking a piece out of one of the cloakrooms. All one side of the building is taken up by a large schoolroom, separable into three class-rooms, corresponding to those on the other side of the hall, by means of sliding partitions, but accommodating rather more children, the numbers in each case being figured on the rooms. Although, in the classrooms, left-hand light is obtained in every case except for a few desks to which there is supplementary back lighting, this is not possible in the schoolroom, the seating of which is planned with the idea of the partitions being open, 72 children having light from the right-hand side, and 70 children from the back. These 70 children have a stepped gallery and continuous benches, as have also the infants in the babies' room, but most of the children are provided with dual desks; and it may be noticed that in all cases the planning and the dimensions of the rooms are both largely controlled by the seating and by the regulation allowances according to the class of desk which is used. The central hall is only 22 feet 6 inches wide, and so is much more suited for corridor purposes than it is for a large assembly. As all the rooms opening out of it have glazed partitions, facility is afforded for control by the head teacher without necessarily entering any classroom.

This building has been ventilated and warmed by a very complete installation of the Plenum system, which is to be more fully described in a later part of this Volume.

The hall is entirely top lighted by means of dormers, with the exception that in each end gable there is a large semicircular window, the cloakrooms being kept low to allow of its introduction. The classrooms are all separately roofed, and there is a gutter between their roof and the schoolroom roof. While this construction is economical, as enabling the central hall to be kept quite low, it has the disadvantage of forming a snow-trap in bad weather, which needs cleaning out with some care,—and even at the best of times any water which collects in a hidden gutter of this sort is always difficult to get away.

Another very complete school on the same system is that now being erected for the Borough of Bexhill from the designs of Mr. H. P. Burke Downing, F.R.I.B.A., which are illustrated in Fig. 5. The plan in this case was selected from over one hundred submitted in open competition, and as it was approved without the slightest alteration by the Education Department, it may be taken as a model plan and worth a good deal of attention. The school is to be built in two parts, the infants' department being erected first, and the girls' department being afterwards added. Like the infants' school at South Shields, it is of one storey only, and on the hall system, and the hall, it will be noticed, runs almost due north and south, while every single classroom has left-hand light provided, and can obtain direct sunlight at some time or other during the day. It is thus almost ideal in its arrangement, and it is a distinctly good point that the classrooms are almost all small, none of them containing more than 50 students at a time. All of them are planned with dual desks except one (the babies' room), and all of them are capable of supervision from the main hall. The infants' entrance is in the centre of the complete building, and as there are 410 of these little children to provide for, their cloakrooms are divided into compartments, so that all do not crush into the same place. Their entrance corridor turns in the usual way, but is very wide, and eventually they all enter into the centre of the hall under a gallery, their entrance being facing the platform and the head-mistress' room at the other end of the hall. The way in which the head-mistress is thus given control of the place is well worth a little study, as is also the planning of a disconnected private lavatory and the stockroom. There is an exit for the infants to the playground quite distinct from the main entrance, for use during the intervals of playtime, when the children run out without putting on hats or other outer clothing. Over the infants' cloak-room and entrance an assistant teachers' room is contrived, and also a gallery, giving them, like the head-mistress, perfect control of the hall, while the main entrance is placed thus also under supervision.

The girls' department is equally well planned, the entrance being at the south end of the building by the side of the head-mistress' room, which corresponds with that of the head-mistress to the infants' school

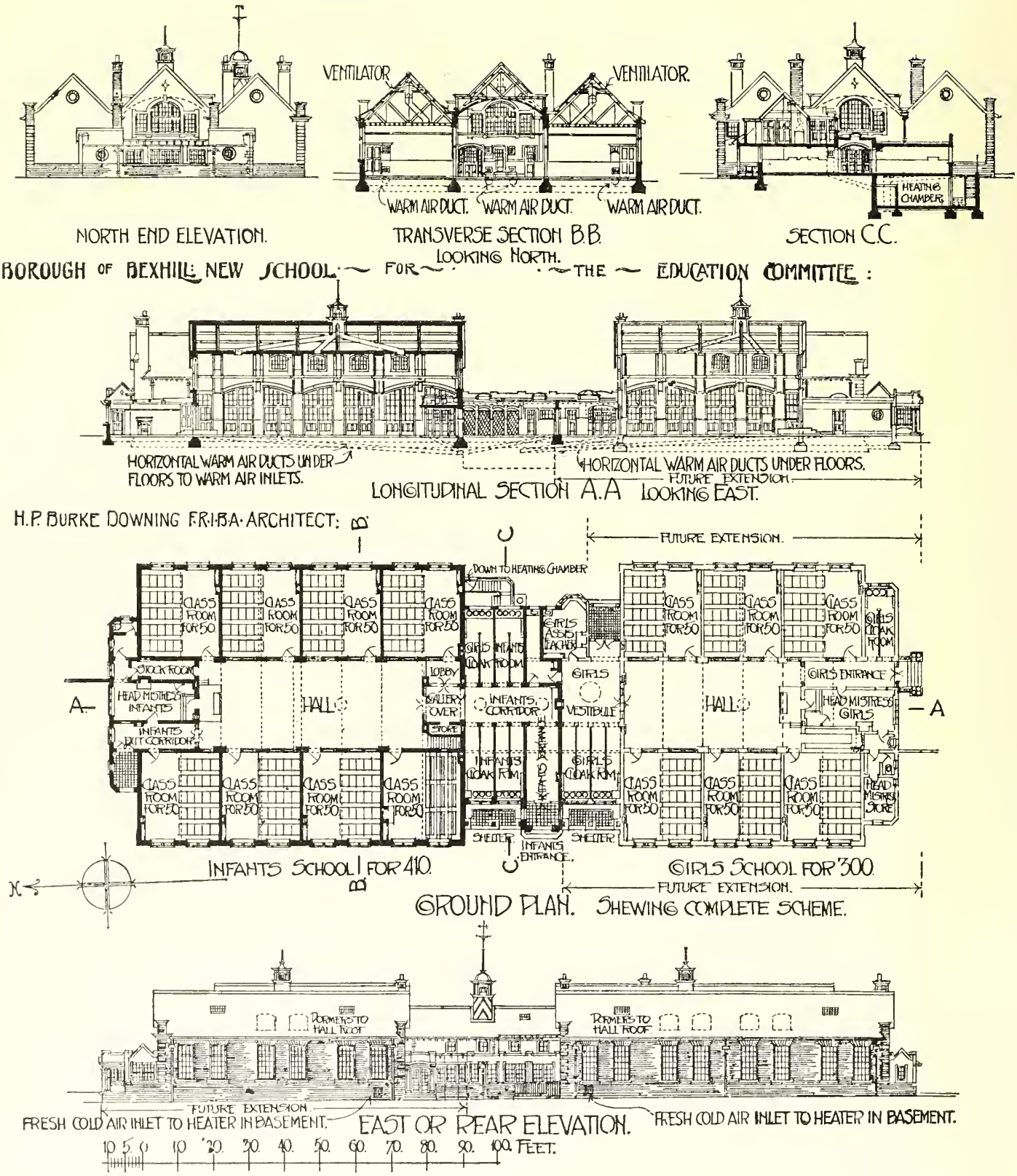

NORTH END ELEVATION.
VENTILATOR
VENTILATOR.
WARM AIR DUCT.
WARM AIR DUCT.
WARM AIR DUCT.
TRANSVERSE SECTION B.B.
HEATING CHAMBER
SECTION C.C.
BOROUGH OF BEXHILL NEW SCHOOL FOR LOOKING NORTH. THE EDUCATION COMMITTEE:
HORIZONTAL WARM AIR DUCTS UNDER FLOORS TO WARM AIR INLETS.
HORIZONTAL WARM AIR DUCTS UNDER FLOORS.
FUTURE EXTENSION
LONGITUDINAL SECTION A.A LOOKING EAST.
H.P. BURKE DOWNING F.R.I.B.A. ARCHITECT:
FUTURE EXTENSION.
DOWN TO HEATING CHAMBER
CLASS ROOM FOR 50
GIRLS ASSIST. TEACHER
GIRLS CLOAK ROOM
STOCK ROOM
HEAD MISTRESS INFANTS
LOBBY
GALLERY OVER
INFANTS CORRIDOR
VESTIBULE
GIRLS ENTRANCE
HEAD MISTRESS GIRLS
HALL
INFANTS WAIT CORRIDOR
INFANTS CLOAK ROOM
GIRLS CLOAK ROOM
STORE
HEAD MISTRESS STORE
SHELTER
INFANTS ENTRANCE
INFANTS SCHOOL FOR 410.
GIRLS SCHOOL FOR 300.
FUTURE EXTENSION.
GROUND PLAN. SHEWING COMPLETE SCHEME.
DORMERS TO HALL ROOF
FUTURE EXTENSION
FRESH COLD AIR INLET TO HEATER IN BASEMENT.
EAST OR REAR ELEVATION.
FRESH COLD AIR INLET TO HEATER IN BASEMENT.
10 5 0 10 20 30 40 50 60 70 80 90 100 FEET.

FIG. 5.

though it is perhaps a little doubtful whether the playground entrance on the east would not more generally be used, as it leads directly into a large vestibule from which the cloakrooms open. Just as the south entrance is under the control of the head-mistress, so is the east entrance under that of the assistant-mistress, as may, perhaps, be best seen in the section given in Fig. 5A. In fact, the general idea of the plan seems to be not only perfect lighting of all parts, but most perfect supervision of the children at all possible times. The halls are lighted in almost identically the same way as in the infants' school at

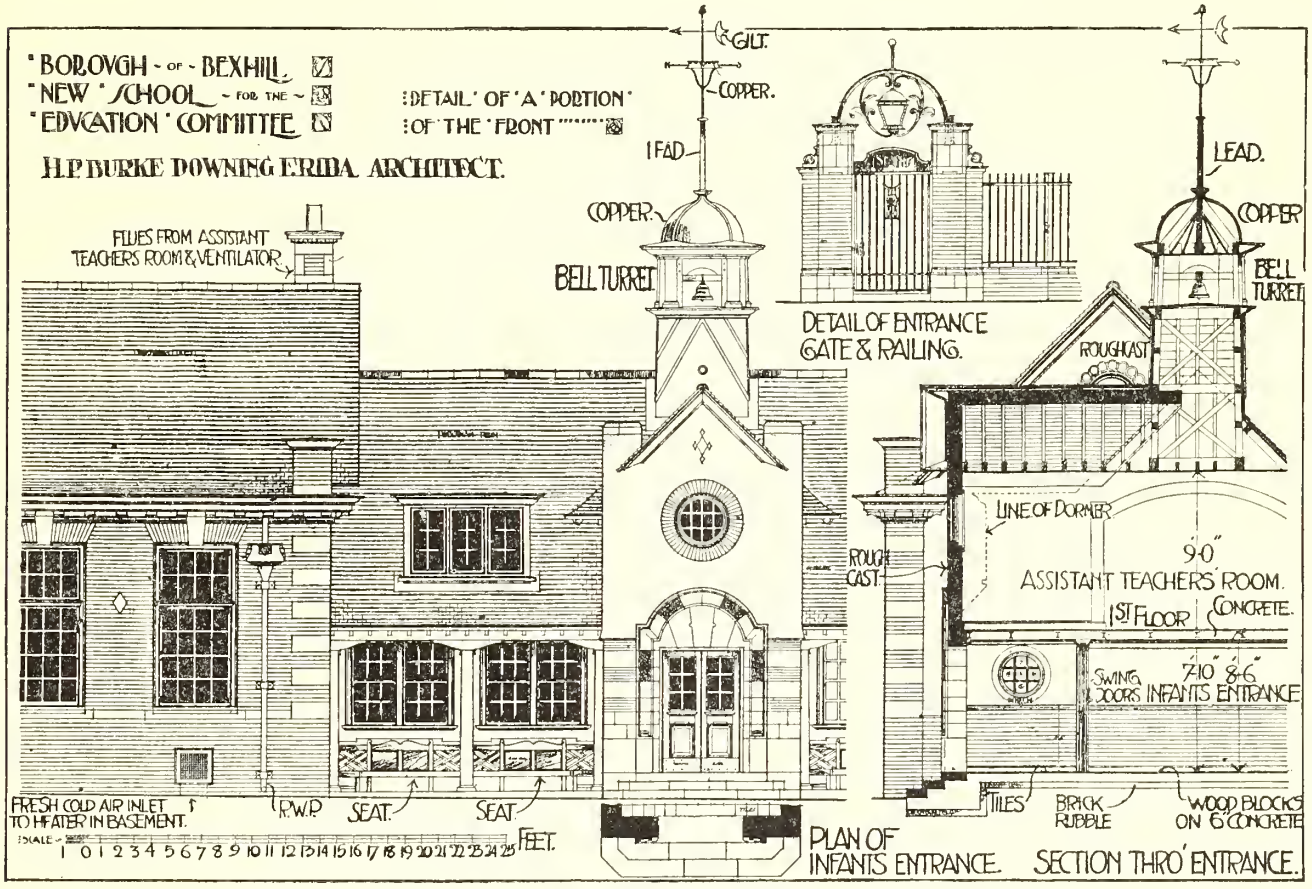


FIG. 5A.

South Shields, and there is the same need for periodically cleaning out the gutters between the hall roof and the classroom roofs, which could have been avoided had money enough been spent on building the hall to a greater height.

When a large school has to be placed upon a restricted area of land it has, in order to provide enough playground space, to be built of two or three storeys in height. Such a school is that in Dean Road, South Shields, designed by Mr. J. W. Donald, A.R.I.B.A., and illustrated in Fig. 6. What is here called the central hall does not now allow classrooms to be built on both sides of it, as top lighting is not possible with a building of several storeys in height. In this instance the best has been done that was possible with a somewhat difficult site. The main building is placed at the corner so as to face Dean Road to the north-east, and it is on this side that the central hall occurs, with corridor extensions at either end leading to classrooms. The whole of the ground floor is given up to boys and the first floor to girls. The boys enter in the front at either end of the central hall, which they do not necessarily pass through, as it is possible to go straight to classrooms without doing so in most cases. Where it is avoidable the corridor extension of the central hall in this way is not always to be commended, as it renders supervision of the classrooms much more difficult than when they open directly out of the hall, the school partaking of the character both of the central hall and of the corridor type. Most of the classrooms, it will be seen, have supplementary lighting as well as left-hand lighting. Both for boys and girls there is a good open playground and a covered shed, from which, as well as from the open, the latrines can be reached; while at one end of the boys' playground is situated the caretaker's house, planned in accordance with regulations, so that no room is necessarily a passage room. There

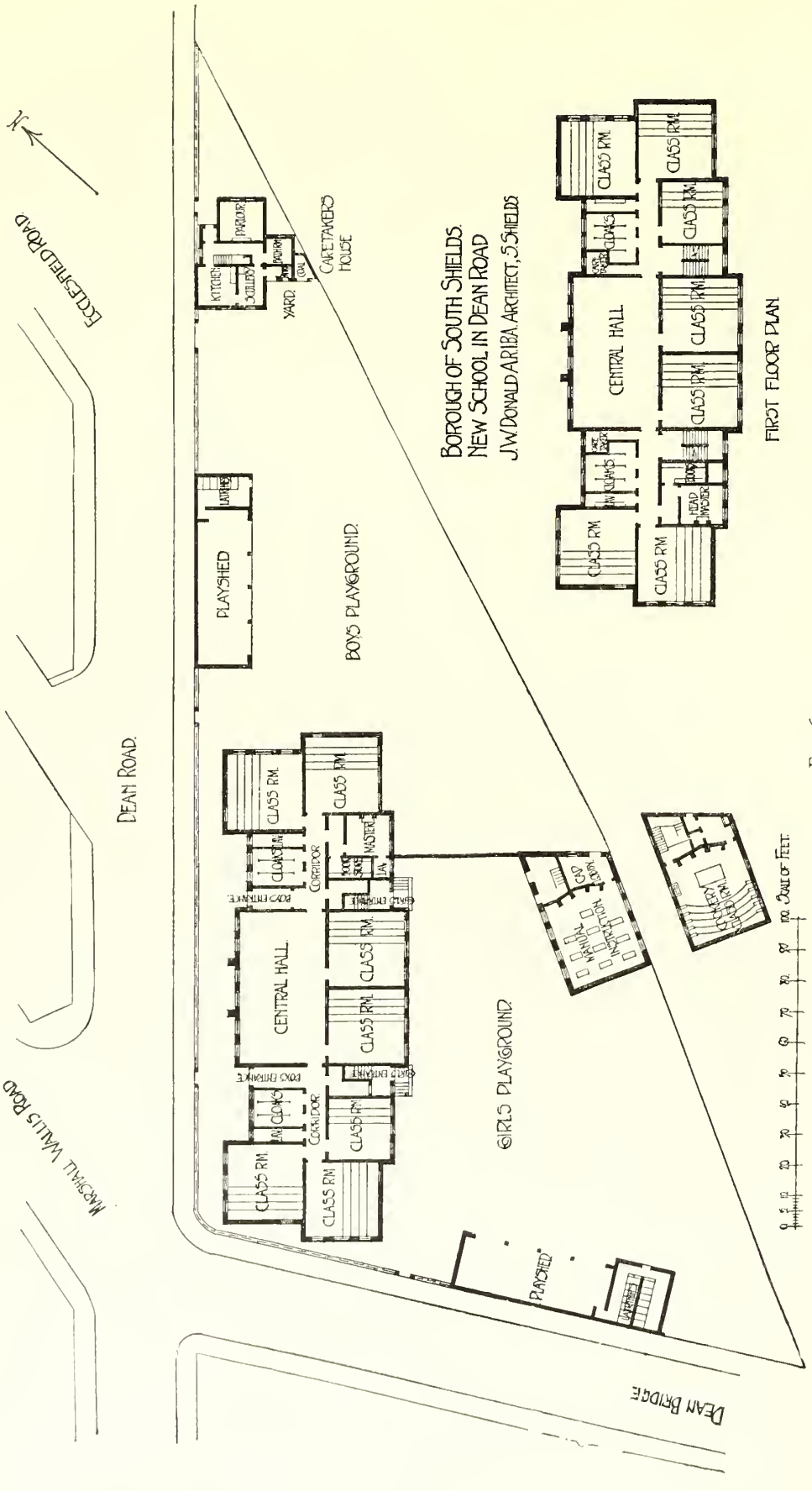
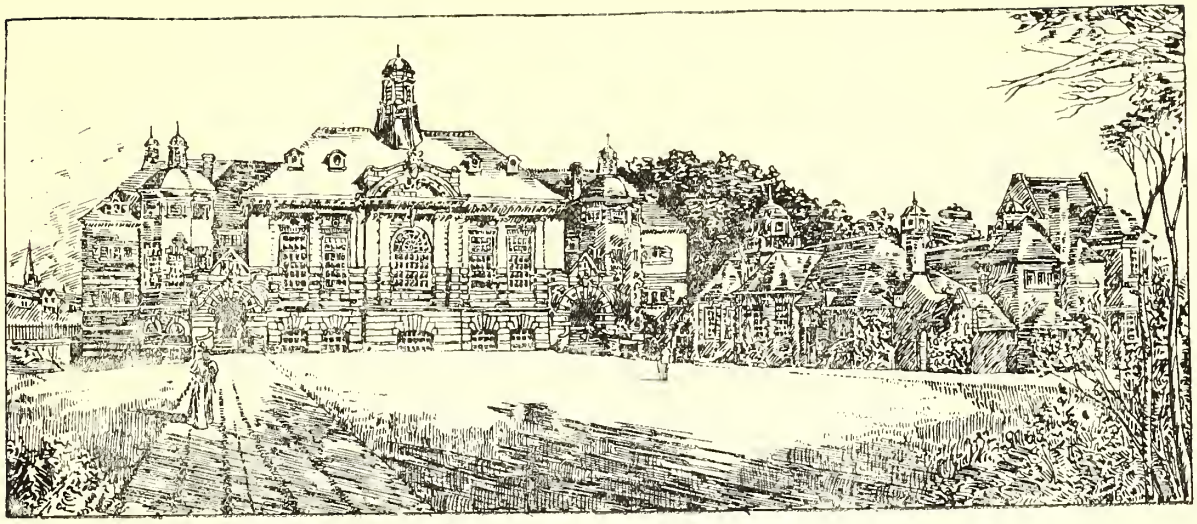
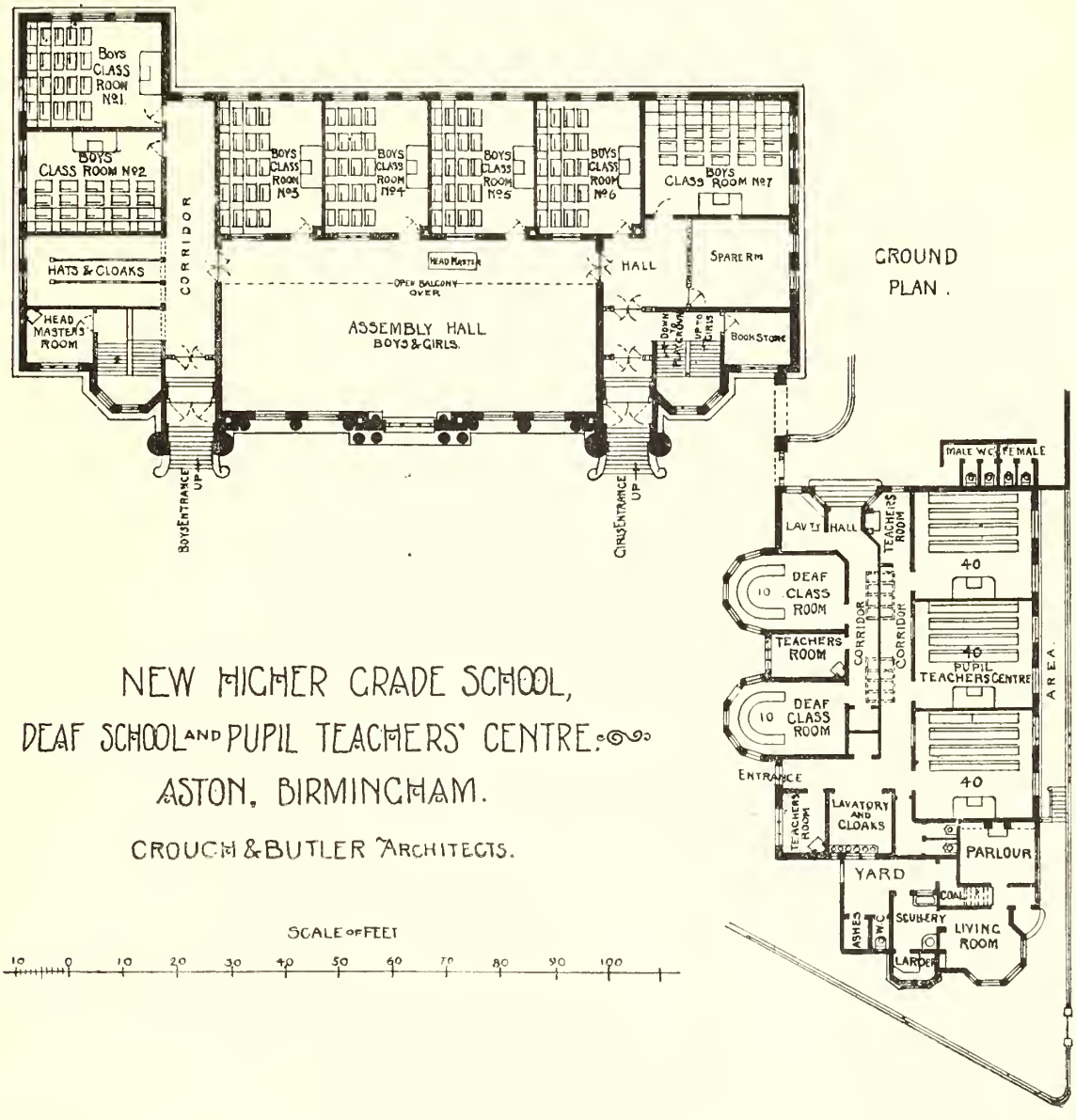


FIG. 6.

is also, on the south-west side of the playground, a detached building which on the ground floor is used by the boys for manual instruction, and on the first floor by the girls as a cookery centre, access being obtained by an open well staircase. This is an unusual kind of staircase to find in elementary schools, for they are almost invariably in short, straight flights, parallel to one another, and separated by brick partitions, thus entirely avoiding the dangerous well-holes and the baluster rail which it is such a temptation for children to slide down, while giving also the opportunity for fire-resisting construction and the consequent provision for a safe means of exit should a fire break out.



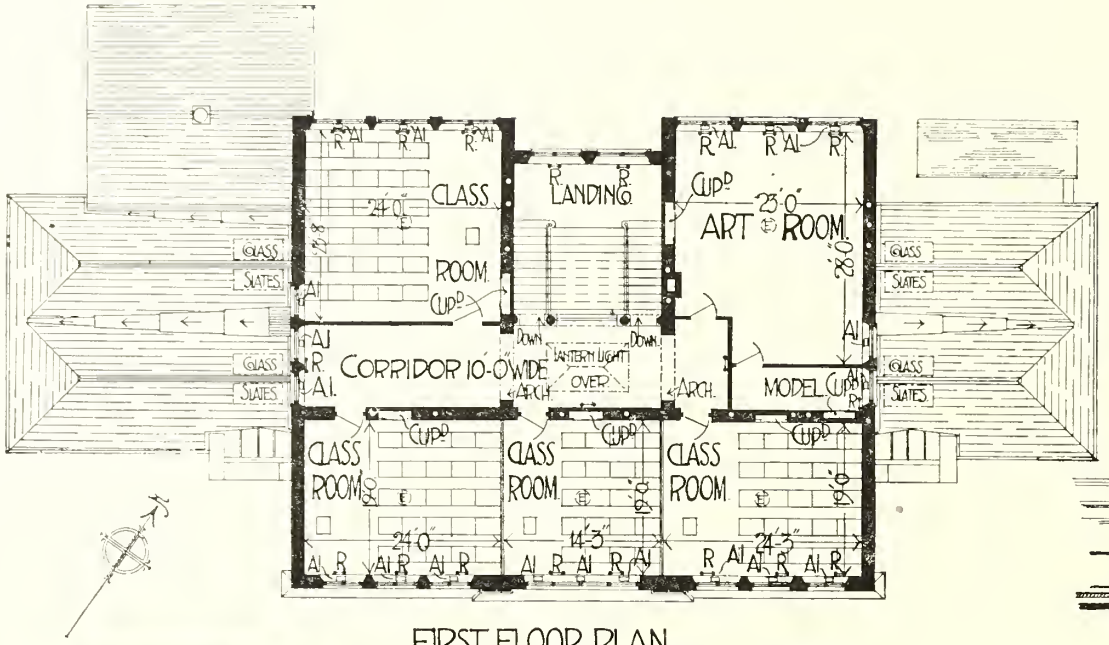


NEW HIGHER GRADE SCHOOL, DEAF SCHOOL AND PUPIL TEACHERS' CENTRE. ASTON, BIRMINGHAM.

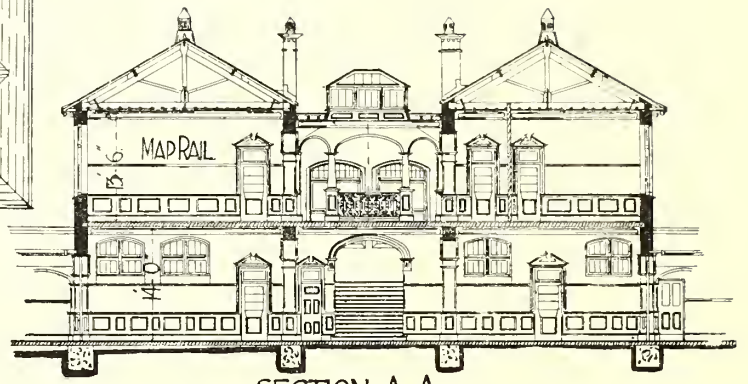
CROUCH & BUTLER ARCHITECTS.

SCALE OF FEET

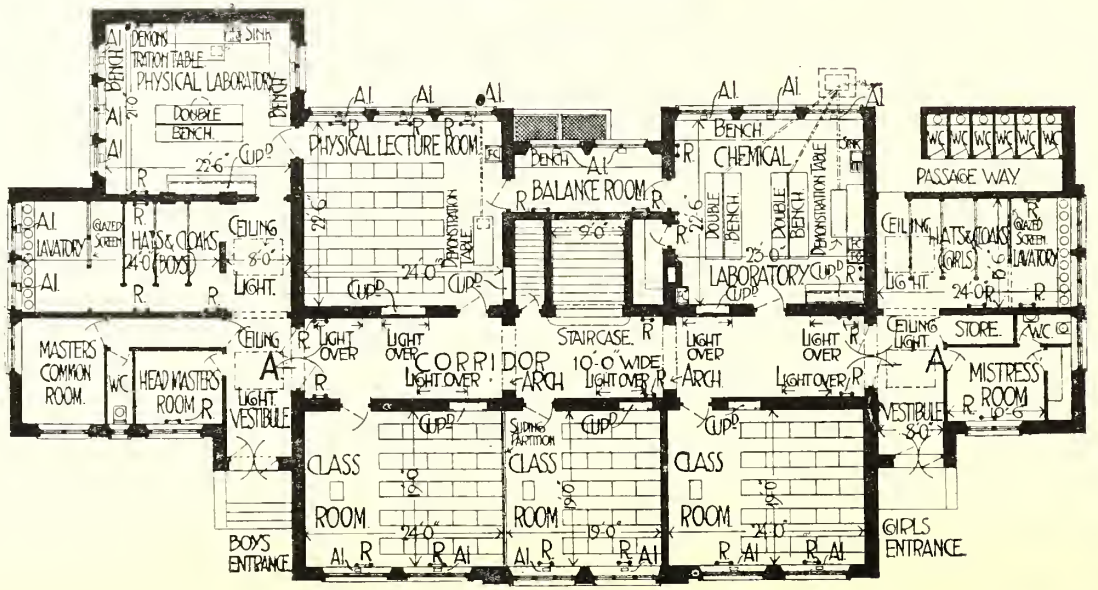
10 0 10 20 30 40 50 60 70 80 90 100



FIRST FLOOR PLAN.



SECTION A.A.



GROUND FLOOR PLAN.

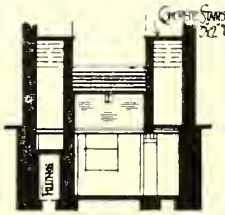
SECONDARY OR TECHNICAL SCHOOL, ST. AUSTELL.

FOR THE CORNWALL COUNTY COUNCIL.

TO ACCOMODATE 200. B.C. ANDREWS M.S.A. ARCHITECT, ST. AUSTELL.

10 5 0 10 20 30 40 50 FEET.

PLAN OF HEATING CHAMBER.



SECTION A.B.

FIG. 8.

CHAPTER IV

HIGHER GRADE AND TECHNICAL SCHOOLS

In general principle there is not much difference between the schools already considered and those which are intended for higher and more specialised instruction. The differences lie much more in detail, in fittings, and in meeting the requirements of the special instruction which is to be given. A mere Higher Grade School, for instance, for teaching general subjects to older students, such as that illustrated in Fig. 7, and designed for Aston, Birmingham, by Messrs. Crouch & Savage, may be almost identical in its general scheme with one of the hall schools considered in the last chapter. Thus there is a large assembly hall in front of the building, with classrooms opening out of it at the back, and also out of an inner hall on one side and out of a corridor on the other. The ground floor is intended to be given up to boys, who enter on the left-hand side of the Assembly Hall into a long corridor which passes through the building from front to back. The entrance is well controlled by the head-master's room, which is situated close to a staircase serving large covered playgrounds below and another floor above, which however, is not accessible to the boys as a general rule. The boys' cloakroom is also, as usual, situated close to the entrance, but the positions of the racks may well be noticed, the gang-ways being each separately entered from the main corridor. The girls' entrance is on the other side of the Assembly Hall, and their cloakrooms are on the first floor, not shown on the plan ; but the hall can be used by both sexes.

Perhaps more interesting, as displaying new features, is the plan of the Deaf School and Pupil Teachers' Centre, which is arranged close to the Higher Grade School and at right angles to it. The two departments are in the same building, but they are quite distinct. The Deaf School is entered from a playground, and the corridor system is adopted, a teachers' room being placed between two classrooms, which are of consider-able size, but accommodate only ten students each. The desks are arranged in a semicircle in a large bay window, the students having their backs to the light, which shines full on the face of the teacher, so that lip movements can be read by the students with ease. A partition wall separates this corridor from another belonging to the Pupil Teachers' Centre, both being top lighted. In this the usual contrivances for perfect control are found more fully developed than in the Deaf School, there being a teachers' room near the entrance and another at the end of the main corridor overlooking the playground. The arrangements in this portion of the school are much the same as in an ordinary corridor school, with glazed partitions between the corridor and the classrooms.

Throughout all the schools hitherto illustrated the position of windows, doors, seats, and teachers' desks are nearly alike, and should be carefully studied by all who hope to succeed in school planning. A small house is attached to the Pupil Teachers' Centre, but it has little that is peculiar in it. It would, however, make a comfortable dwelling for the principal, pro-vided he was content with one sitting-room and a good sized kitchen.

The new Technical School at St. Austell, Cornwall, has been planned by Mr. B. C. Andrew, M.S.A., as a corridor school in two storeys, as shown in Fig. 8, the corridor being well lighted, although it occurs in the middle of the building, by a large staircase window. There are separate entrances for boys and girls at either end of the building, with somewhat similar arrangements for access to cloakrooms, very much as they are found in ordinary schools, with the additional provision, on the boys' side, of a separate head-master's room, where parents can be interviewed, close to the entrance. These end portions are not carried up above the ground floor. The main building faces south-east, and three classrooms on each floor have windows opening on this side. On the north-west side, on the ground floor, are placed the physical lecture-room and the chemical laboratory, and between them is the balance-room, the windows occupying almost all the wall space so as to admit diffused light without direct sunshine. The balance-room is accessible in this way both from lecture-room and laboratory, while the physical laboratory can be entered either directly from the lecture-room or independently. These are all fitted up with considerable care. There is a demonstration table in each of the laboratories with the necessary appliances, besides benches at which the student can work, and the necessary fume closets, even the lecture-room being similarly fitted, the lighting in every case being carefully studied. Every room, it will be noticed, contains a cupboard for apparatus, this being generally contrived in the thickness of the internal walls, which in that district would be built of stone.

The upper floor is entirely devoted to classrooms,

except for the art studio, which is placed at the north corner, with a small model's dressing-room opening out of it.

The selection of the positions of the rooms is in accordance with usual practice. For instance, the two laboratories, particularly the chemical laboratory, must be on the ground floor on account of the drainage, as water is largely used in them. The physical laboratory and balance-room must also be on the ground floor, in order that the delicate instruments may be placed on benches solidly built up on a solid foundation. While the physical laboratory may have windows exposed to direct sunlight, and in fact is the better for them for certain experiments relating to light, this is not the case with the chemical laboratory or the balance-room. Similarly, the art studio does not require direct sunlight, but wants a large amount of window space, and some roof lighting which can be screened when necessary. The room is consequently obliged to be placed so as to face the north or north-east, and to be on the top floor. Classrooms for ordinary instruction, however, follow the rules already laid down for the admission of as much sunshine as possible, and it will be seen that the desks are arranged exactly as they would be in elementary schools.

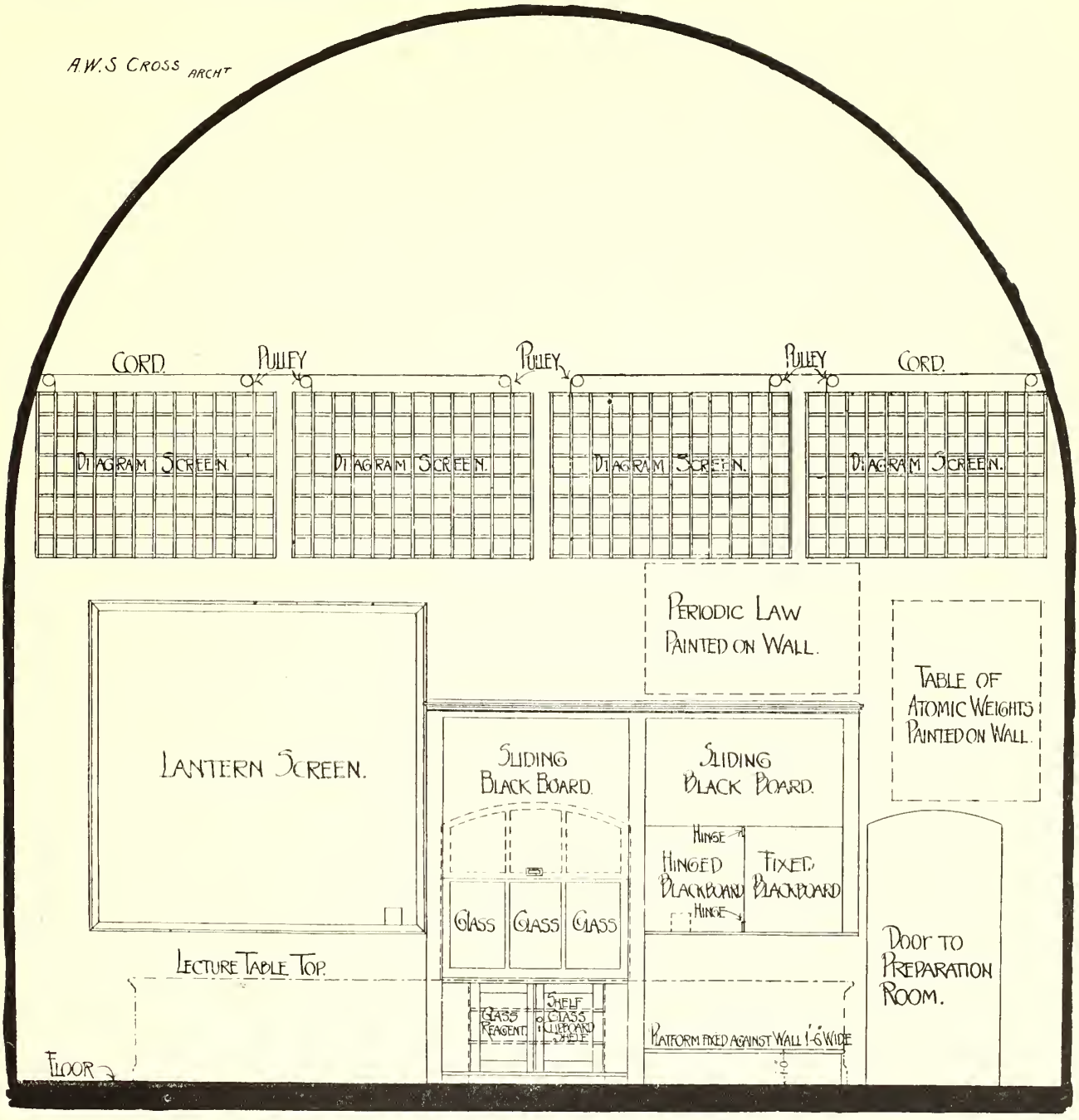
Fittings

In the matter of fittings for technical schools it would perhaps be difficult to improve upon those designed for the Manchester Technical School, of which the architect is Mr. A. W. S. Cross, F.R.I.B.A. Fig. 9, for instance, illustrates one end of the chemical lecture theatre, where it adjoins the preparation-room. Communication can be obtained at will through an opening having two glazed sliding sashes, one on either side, through which objects can be passed from one room to the other without using the door. The space in the thickness of the walls between the two glazed sashes is, however, intended primarily to be used as a fume cupboard, and, by means of the glass on each side of it, experiments which take place within it can be watched with great perfection by the students, while it is accessible, if necessary, from either room. On the lecture-room side the glazed sash can, when desired, be covered by a sliding blackboard, made, like the sashes, to rise and fall with counter-balance weights. Beneath this window are small cupboards, and in front of it, separated by a small gangway, is the lecture table. On one side of the opening there is a large permanent lantern screen, and of course the windows are provided with dark blinds, so that daylight can be shut out when the lantern is in use, as it frequently must be during the delivery of scientific lectures. Another portion of the wall space is covered by a series of blackboards, the outer one of which is made to rise and fall, while the inner one has half its surface hinged. Thus a drawing on the upper part of a blackboard may easily be made while the instructor is standing on the floor, and then the board be raised to display the drawing to the class. As instruction is sometimes given by diagram, as well as by blackboard drawings and lantern views, a series of diagram screens occupy the upper part of the wall, capable of being raised and lowered by means of pulleys.

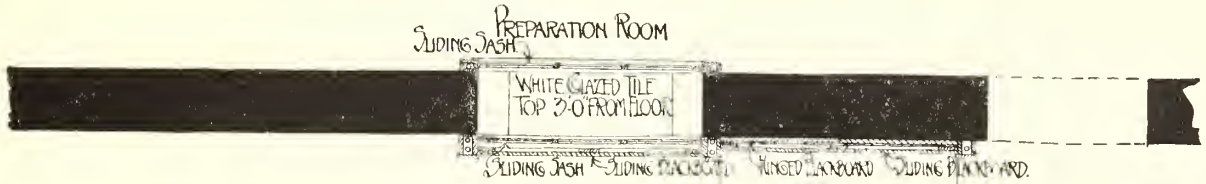
Fig. 10 illustrates some of the details of the same room to a larger scale. From a careful study of this it should be possible to devise any similar arrangement of sliding and hinged blackboards, and attention may be drawn to the use of the friction rollers. The full details of the fume cupboard are also of some importance, with its tiled flooring, and the reagent cupboard underneath, again accessible from each room. The large scale detail shows a strip of indiarubber to be attached to the inner side of the upper sash, so as to make the fume cupboard air-tight, this being a most necessary provision ; and it will be seen that putty is not trusted for fixing the glass, but that hard-wood beads are used as is usually done in shop fronts. The flue from the fume cupboard is contrived in the thickness of the wall, and there is a gas jet provided so as to give an induced current of air if needed.

A detail of the working benches of the organic laboratory, shown in Fig. 11, is equally important. The bench is double, there being spaces for four students on each side, the counter top at which each student works being separated from that of the opposite student by a glazed stoneware channel, while there is a sink for every four students. Of course, ample water supply is provided, and both channel and sink possess carefully contrived and specially made wastes for rapid discharge into a channel below the floor level. Right along the centre of the bench from end to end there runs a water pipe with taps, and vacuum is similarly laid on ; and above it are two rows of shelving, while beneath the counter each student has four drawers and two large cupboards with shelving, there being long boxes for the storage of glass tubes in each of these cupboards. These are placed in pairs and are open at alternate ends, passing right through from side to side of the double bench, enabling each student to store tubes of considerable length.

CHEMICAL LECTURE THEATRE, MANCHESTER MUNICIPAL TECHNICAL SCHOOL.



ELEVATION.



LECTURE THEATRE PLAN

FIG. 9.

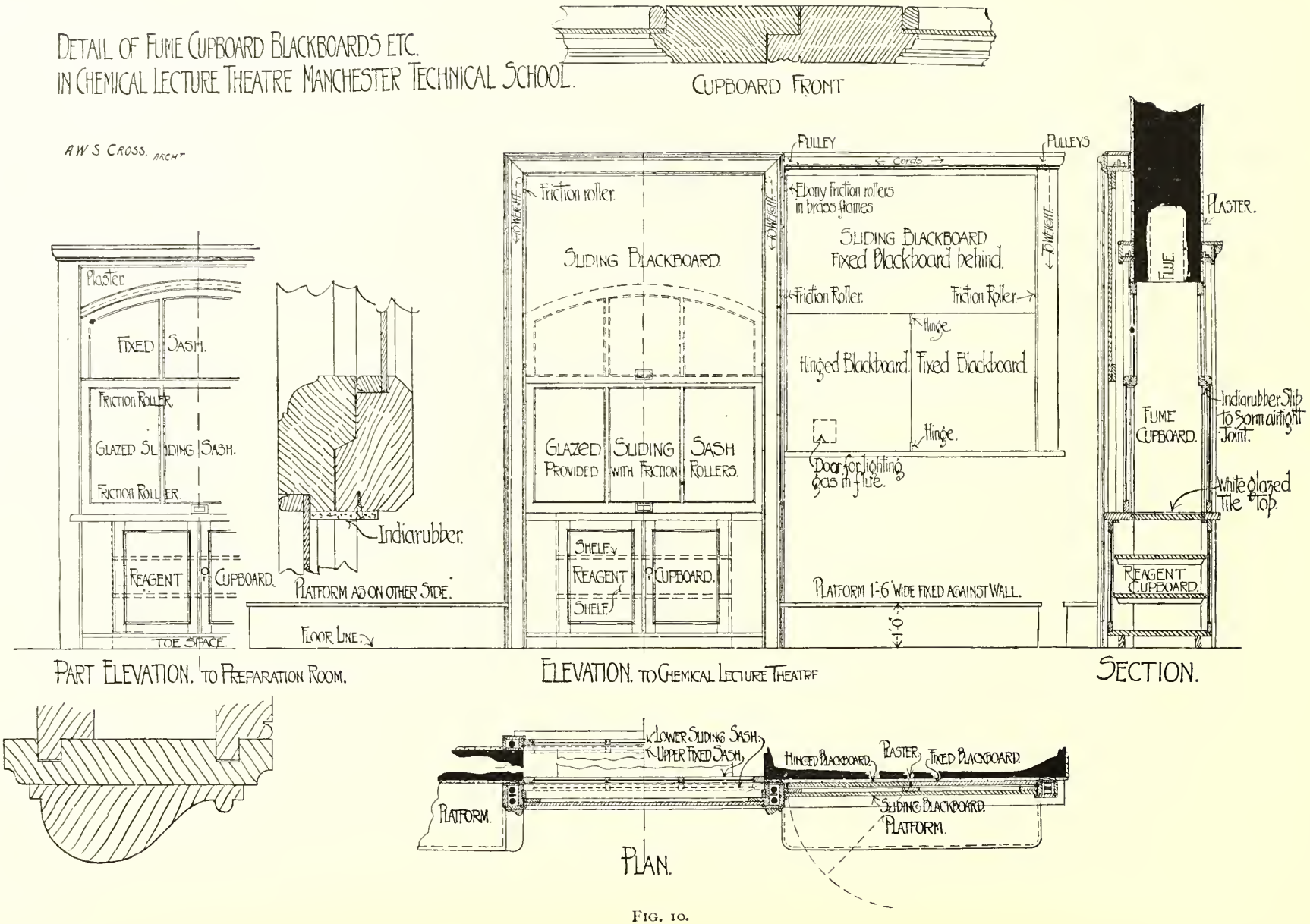

DETAIL OF FUME CUPBOARD BLACKBOARDS ETC.
IN CHEMICAL LECTURE THEATRE MANCHESTER TECHNICAL SCHOOL.
A W S CROSS, ARCHT
CUPBOARD FRONT
PULLEY
PULLEYS
Cords
Friction roller.
SLIDING BLACKBOARD.
WEIGHT
WEIGHT
Ebony friction rollers in brass frames
SLIDING BLACKBOARD
Fixed Blackboard behind.
Friction Roller.
Friction Roller.
Hinge.
Hinged Blackboard.
Fixed Blackboard.
Hinge.
Door for lighting gas in flue.
PLASTER.
FLUE.
Indiarubber Slip to form airtight Joint.
FUME CUPBOARD.
White glazed Tile Top.
REAGENT CUPBOARD.
Plaster
FIXED SASH.
FRICTION ROLLER.
GLAZED SLIDING SASH.
FRICTION ROLLER.
Indiarubber.
REAGENT CUPBOARD.
PLATFORM AS ON OTHER SIDE.
TOE SPACE.
FLOOR LINE.
GLAZED PROVIDED
SLIDING WITH FRICTION
SASH ROLLERS.
SHELF
REAGENT CUPBOARD.
SHELF
PLATFORM 1'-6" WIDE FIXED AGAINST WALL.
1'-0"
PART ELEVATION. TO PREPARATION ROOM.
ELEVATION. TO CHEMICAL LECTURE THEATRE
SECTION.
LOWER SLIDING SASH.
UPPER FIXED SASH.
HINGED BLACKBOARD.
PLASTER.
FIXED BLACKBOARD.
PLATFORM.
SLIDING BLACKBOARD.
PLATFORM.
PLAN.

FIG. 10.

DETAIL OF WORKING BENCHES, ORGANIC LABORATORY.

EACH BENCH TO ACCOMODATE 8 STUDENTS.

A.W.S. CROSS, ARCHITECT.

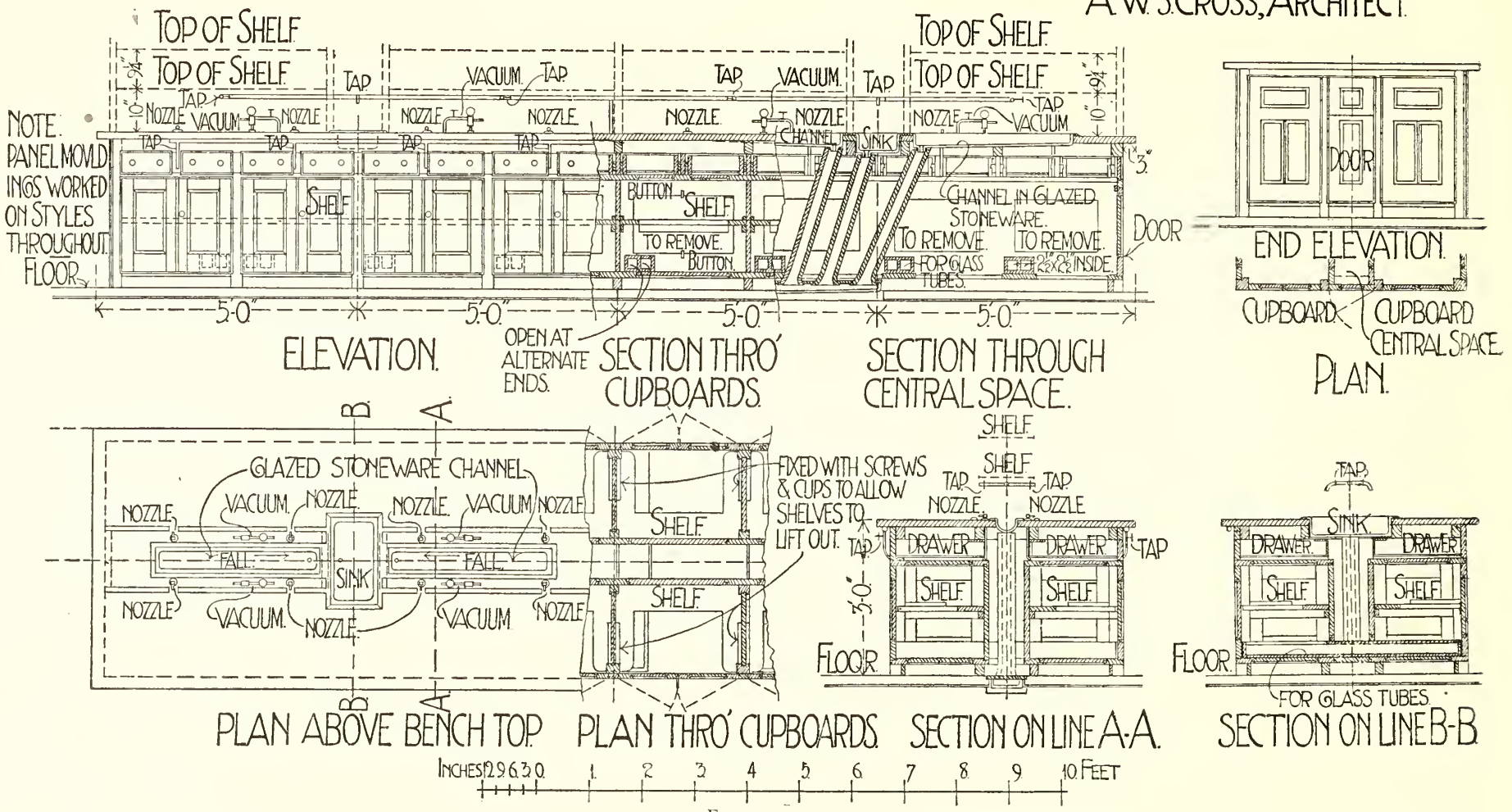


FIG. 11.

CHAPTER V

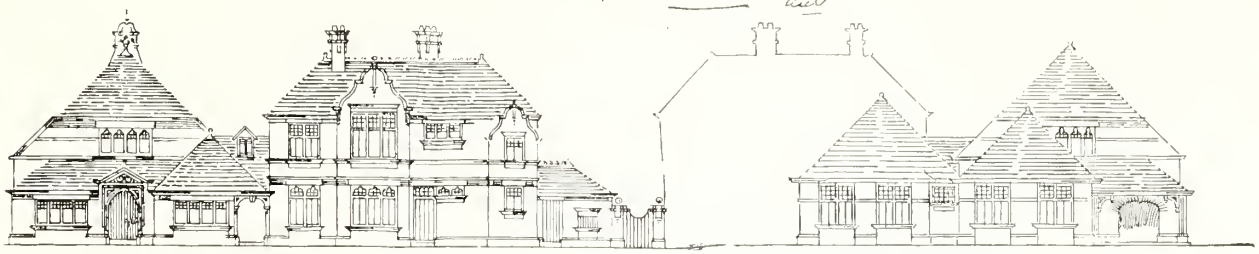
PRIVATE AND SPECIAL SCHOOLS

As the planning of private schools is not bound by any hard and fast rules laid down by an educational authority, there is a considerable amount of freedom if not of laxity in their planning. In fact, the majority of private schools are not specially built for that purpose, but are obtained as they best can be by altering private houses. This is unfortunate, and far from being really satisfactory. Whenever an architect is consulted, however, it is now his usual practice to conform as nearly as possible to the regulations of the Education Department, recognising that these are the outcome of long experience, and for teaching purposes, as well as for supervision, are difficult to improve upon. Thus many of the modern High Schools are exceedingly like public elementary schools in their arrangement. There are, however, a large number of private schools which cannot quite be treated in this way. There is a marked desire upon the part of certain parents for something different from the board school, and this requirement is not to be met altogether by improving the elevation. More privacy is looked for, such as is to be found in a private house. It is also generally necessary to provide a dining-room for the use of the students, as, in the majority of cases, at least some of these are boarders, while others stay to lunch. In this way new elements are introduced into the problem which an architect has to solve, while each case presents as a rule some other special requirements calling for the exercise of some skill upon the part of the designer. This is the case in each of the examples illustrated in this chapter.

To the Day School for Girls (Plate I.) it was desired to attach a Concert Hall which, while it could be used as an assembly room for special occasions by the school, could also be let off for entertainments during the holidays. The school thus partakes somewhat of the character of an ordinary hall school, but has this distinction, that a separate corridor was necessary between the hall and the classrooms, and that provision had to be made for reaching the stage from one end of this corridor, when some of the classrooms could be utilised as greenrooms. The classrooms would be under supervision from the corridor through glazed screens, but amidst them was placed the music-practising room, top lighted and surrounded by thick walls, close to an external passage for access to the heating chamber. The head-mistress' study was placed so as to command the girls' entrance, but it was of a more private character than is usual in elementary schools, for it was entered from a passage in the private house, from the end of which access to the school corridor is obtained. Any girls, however, going through from the house to the school would have to pass the glazed partition of the study, unless they went through the dining-room, which could be entered from either the house passage or the school corridor. The mistress' house was necessarily planned with some considerable regard to appearance and comfort, and contains, on the ground floor, a drawing-room and large kitchen, from which the dining-room can be served directly through a hatch. It was intended that both mistress and students shall use the same dining-room, which is of large size. The upper floor contains three bedrooms and a bathroom, besides a dormitory which is large enough for eight pupils. The school was intended to be primarily a day school, but it was expected that there would be a few boarders, and as accommodation for them could be provided in this way at a very small capital outlay, it was thought better not to reject this means of adding considerably to the income, though the head-mistress was one who did not much care for the responsibility of boarding pupils. It will be noticed that a cycle shed was provided at the back, and that the corridor would be top lighted. The elevation is of a simple and homely type, as far removed as possible from that to be found in schools, either elementary or advanced, built by public educational bodies.

Sandroyd School (Fig. 12), designed by Messrs. Treadwell & Martin, is a much more complete establishment. It is entirely a boys' boarding school, fully equipped in every way for its purpose; but it cannot be said to have been planned in accordance with the principles already discussed. One end of the site is given up to the headmaster's private house, which is a large and comfortable residence, his study opening out of his private hall, but close to a door at the end of the long main school corridor, which has classrooms on one side and a large dining-hall, centrally placed on the site, on the other. Off this main corridor there is a boys' staircase, and at its farther end it is crossed by another corridor with an external entrance, serving still more class-rooms and a masters' common room. Each part of the building is well departmented. The master's house, it will be noticed, has its reception portion perfectly distinct from the servants' portion, which is

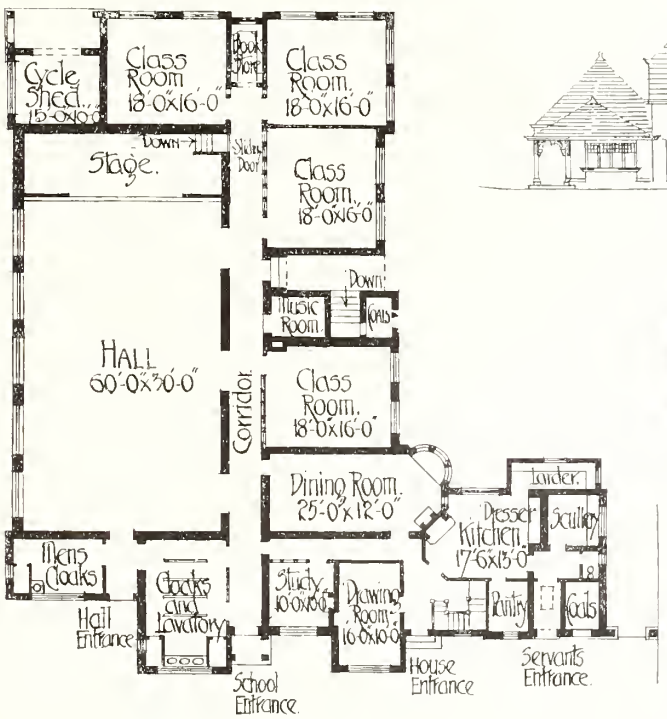
PRIVATE DAY SCHOOL FOR GIRLS.



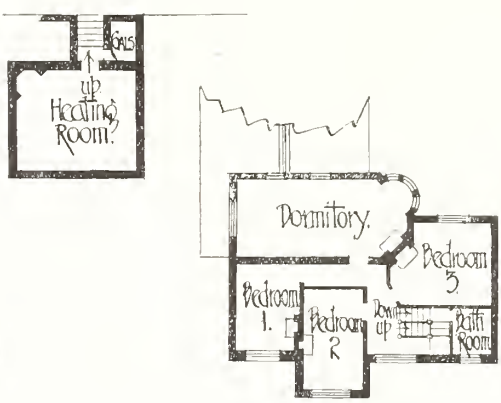
FRONT ELEVATION.

BACK ELEVATION.

SIDE ELEVATION.



GROUND FLOOR.

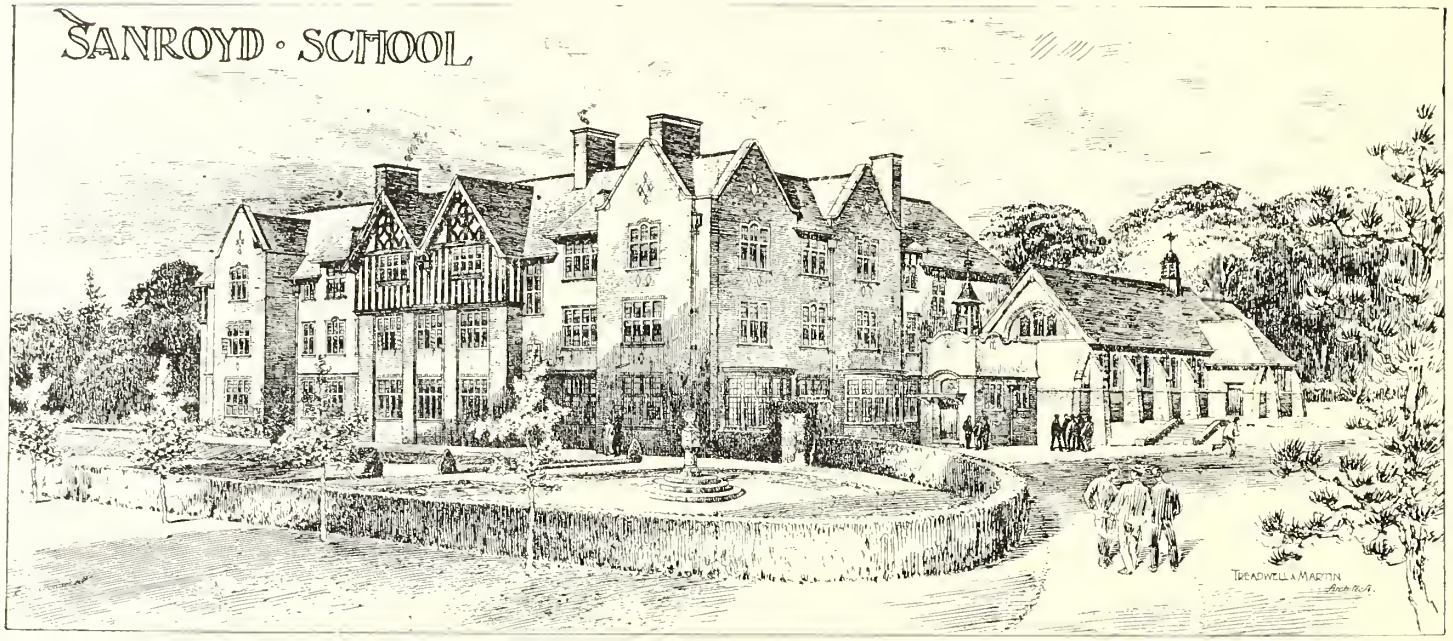


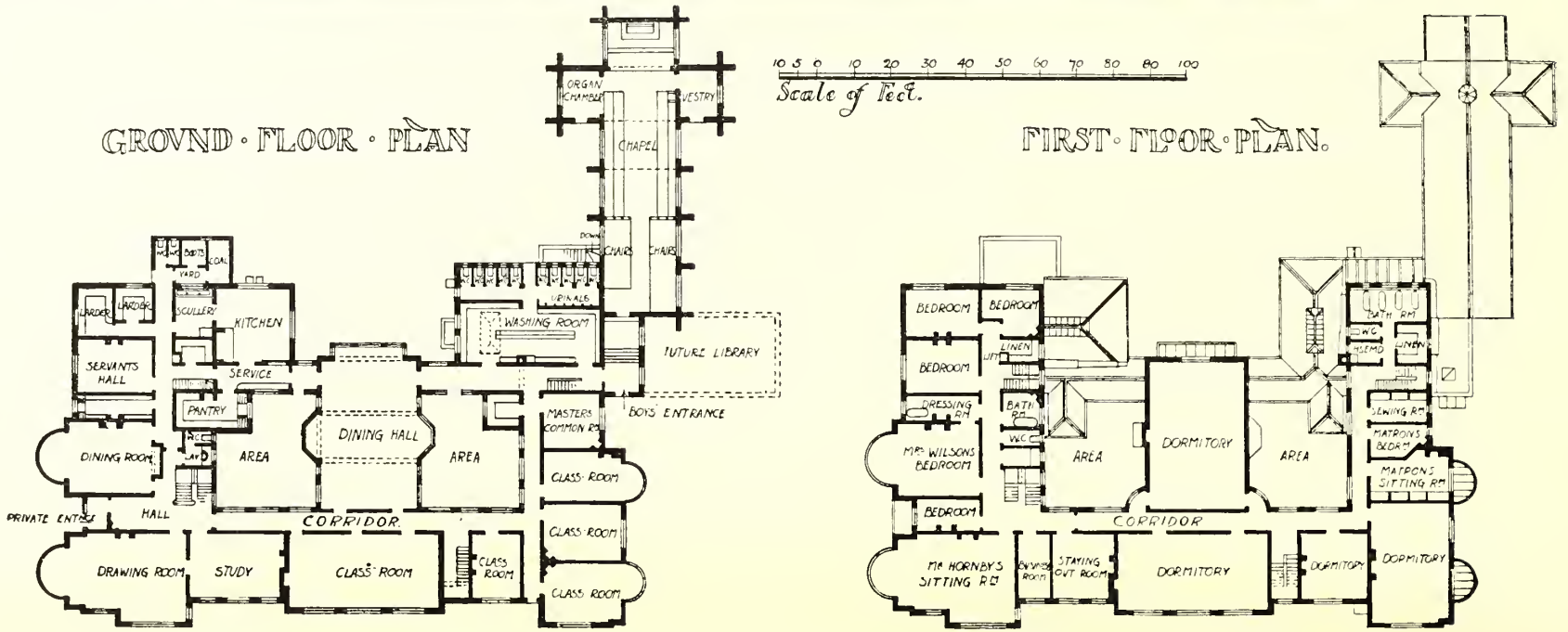
FIRST FLOOR.

very skilfully planned so as to serve either the general dining-hall or the house, with ample kitchen, larder, and pantry accommodation, and a large servants' hall. The kitchen is top lighted as well as side lighted. In the boys' portion of the school the classrooms are controlled at one end by the head-master's study, and at the other by the assistant-masters' common room, in which there is a window commanding the boys' entrance. There is a back passage way here, leading through from the far end of the dining-hall to the boys' entrance, and cutting off the classrooms from a large washing-room, such as is most valuable at a boarding school for use after cricket or football. The w.c.'s and urinals are reached through the washing-room. The boys' entrance also leads directly to the chapel, which is seated inwards, after the usual college fashion, throughout the greater part of its length, and has a number of chairs arranged in the ordinary way at the western side of the screen for the use of the servants.

On the upper floor the fact that the plan has been based on the letter E is more noticeable than on the ground floor, as several portions are not carried up. Again, the house is distinct from the school, but with a communicating door on the main corridor, close to which and near the study is a small room called the "staying-out room," in which the boys can be placed who are suffering from slight ailments such as preclude their taking part in the school work while not of sufficient severity to need their being sent to the outlying infirmary. The dormitories are placed over the classrooms, and as there are two staircases, besides means of communication with the master's house, there is ample provision for escape in case of fire. At the farther end of the dormitories from the house are placed the matron's rooms, with her sewing-room, linen-room, and the bathrooms. The absence of a general assembly hall will be noticeable, but it is rarely needed in a private boarding school. Any general notices can always be given out in the dining-hall, and probably great receptions and lectures to the whole school would seldom take place. Plans are only given of two floors, but the perspective shows that there is yet another, and the school is therefore for a private boarding school, rather a large one.

The Western Theological College, designed by Mr. H. Dare Bryan, F.R.I.B.A., is, as will be seen by Fig. 13, a somewhat special school specially treated. With men to deal with instead of children, and these educated men of a high class, close supervision is not only unnecessary but might be looked upon as somewhat of an insult. Consequently the master's house is a distinct establishment, communicating with the school itself through the principal's study and the ante-chamber to the library, from which a committee-room also opens, in convenient juxtaposition both to the principal's and to the main entrance. The school itself, including the library, has been planned as an architectural composition, on an axial line which bisects the angle formed by Hampton Road and Cotham Road. The main entrance is on the axis, and leads across a passage way to a large dining and assembly hall having a gallery round it and lighted by clerestory windows at a high level. The plan of this hall is of mediæval type, with a buttery at the far end, through which the kitchen is reached, there being a small bedroom and sitting-room attached as servants' quarters. Thus the students' dining-room is served entirely independently of the principal's house. The students have a separate entrance, from which they pass through a cloakroom to an inner hall, where a staircase rises, and out of which opens a common room, balancing the library in another wing, both of these being comfortable rooms, with large recessed fireplaces in them. It is on the first floor that all the instruction would be given, and the lecture-rooms there, two of which are large while one is small, have been planned to a great extent for architectural effect. In fact, in such a building and with such a class of students, class teaching, as understood in children's schools, would be entirely out of place, and the arrangements have consequently to be different. There would be much more private study by the students themselves, and while some of the teaching would be by lecture, a good deal would be by individual instruction.

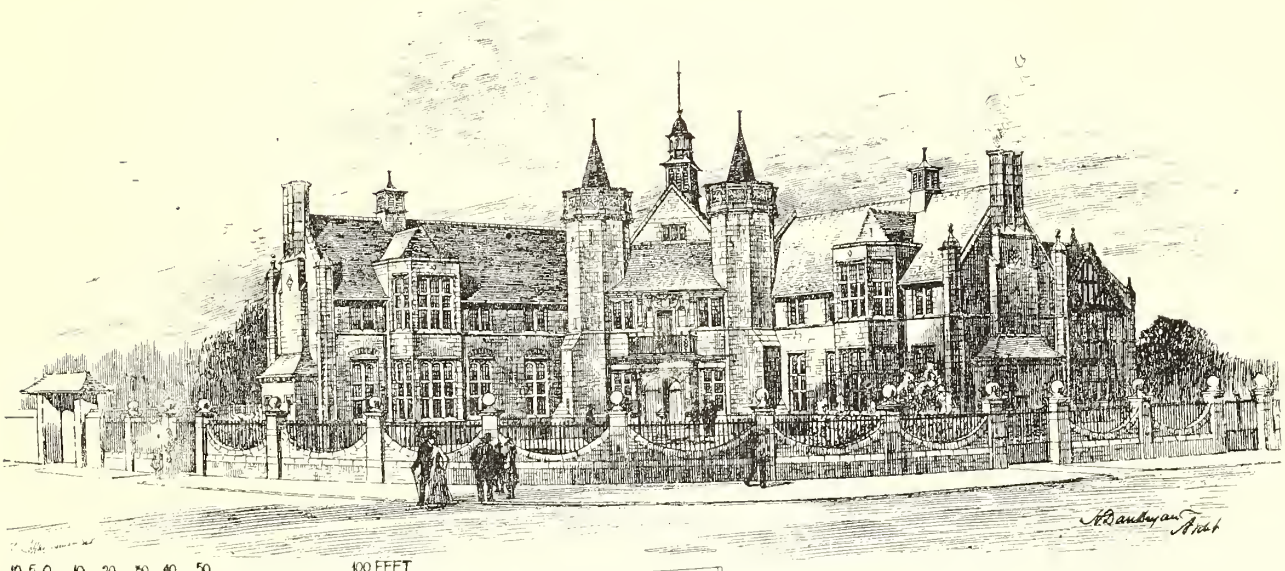


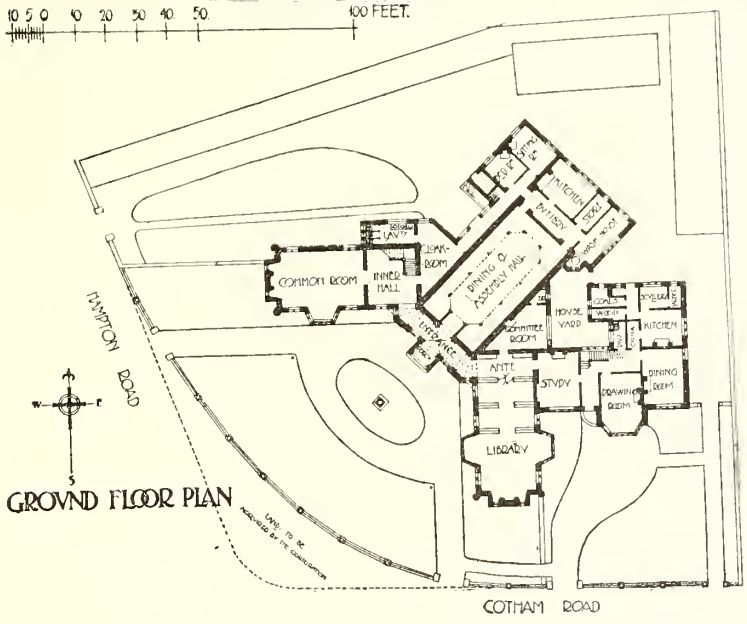


TREADWELL & MARTIN ARCHITECTS

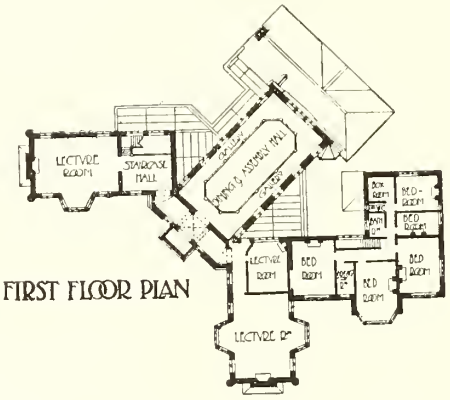
FIG. 12.

THE WESTERN THEOLOGICAL COLLEGE • BRISTOL.





GROUND FLOOR PLAN



FIRST FLOOR PLAN

Mr H. DARE BRYAN. F.R.I.B.A. ARCHITECT.

FIG. 13.

CHAPTER VI

HOSPITALS ON OPEN SITES

Hospital planning, like school planning, has tended of late years towards certain recognised types which are more and more rarely departed from. There are no such definite regulations as those upon school planning, yet the general conditions are just as perfectly understood, the ruling principle being that of perfect ventilation, and disconnection of the various parts, combined with ample air space in the wards. Perhaps the general system can be most easily followed by considering it in relation to Fig. 14, which illustrates the general arrangement of Bedford County Hospital, designed by Mr. H. Percy Adams, F.R.I.B.A. It will be seen that in the front of the site there are two great blocks, of which one is devoted entirely to out-patients, and is kept quite distinct from everything else connected with the hospital. The other great block at the front is devoted to administrative purposes, and is itself divided into two parts, the front portion containing offices, and the back containing the kitchens and stores. These two portions are connected only

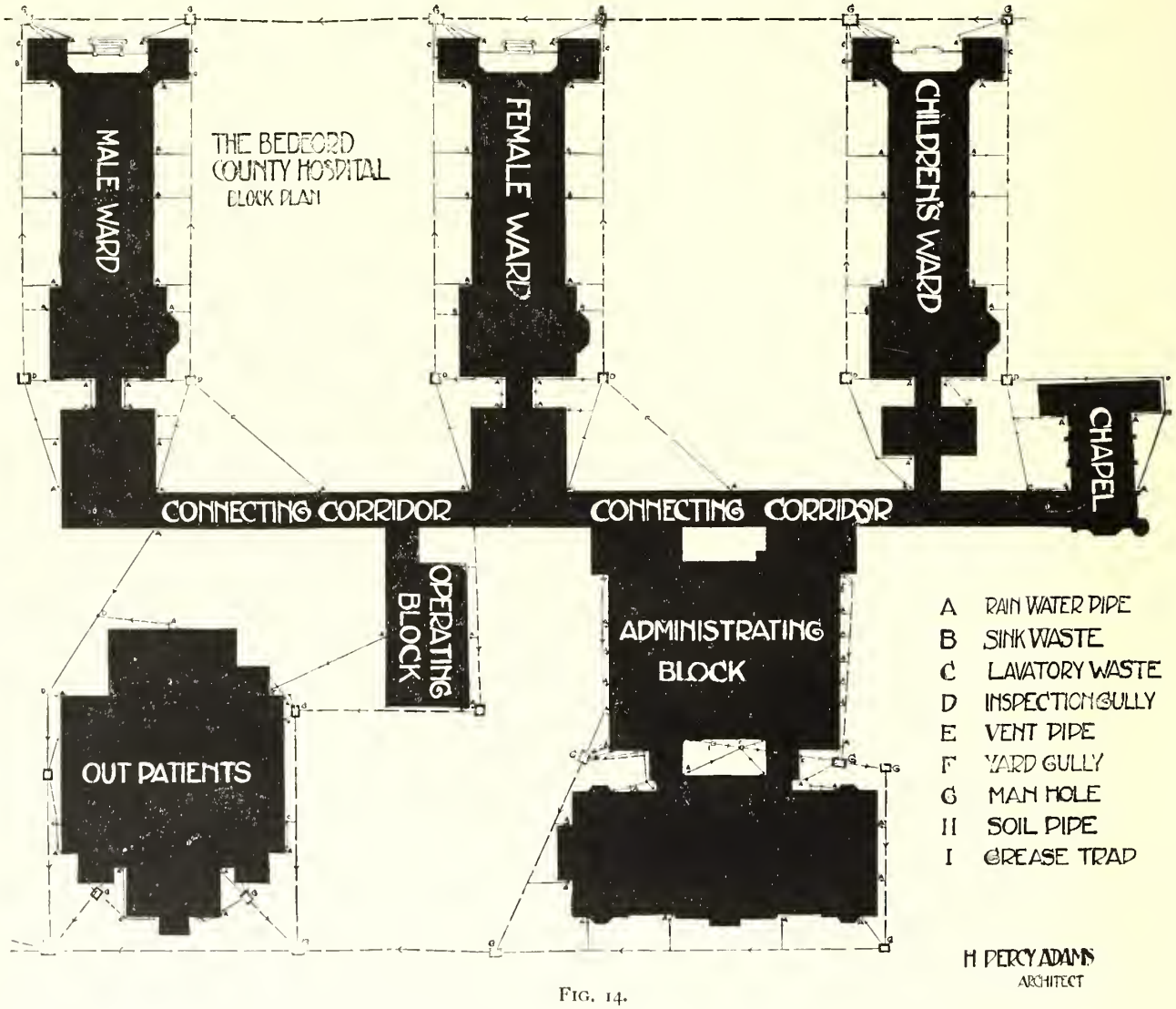


Fig. 14.

by narrow corridors, which, as will be seen presently when the detailed plans are considered, have windows on both sides, and are practically mere covered passages, so that the air blows through and entirely separates the offices from the kitchens. Somewhat similar, but not quite such perfect, disconnection occurs between the kitchen block and a long connecting corridor which passes from end to end of the site parallel with the front. This corridor again has windows on both sides, and in many hospitals even the windows are absent, and it is nothing more than a paved pathway with a light roof over it. Along the corridor tram lines are carried, on which trolleys can be wheeled for the conveyance of food, while the corridor is wide enough to enable patients to be carried with ease along it on hand ambulances. At one end of the connecting corridor is found the chapel, for use by the nursing staff and convalescents, while the wards branch off from it almost invariably at right angles. These are kept always at least as far apart as their height if space permits, the least distance allowable being generally considered to be 40 feet. Whenever it is possible these wards are made to run north and south, with their more distant end towards the south, so that the sunlight may enter at all hours of the day. Occasionally, however, the wards are paired, one occurring on the north and one on the south side of the connecting corridor in the same axial line, but this is not done unless the site is somewhat restricted, or unless it be desired to reduce the length of the connecting corridor, which is difficult of supervision and proper management if it be too long.

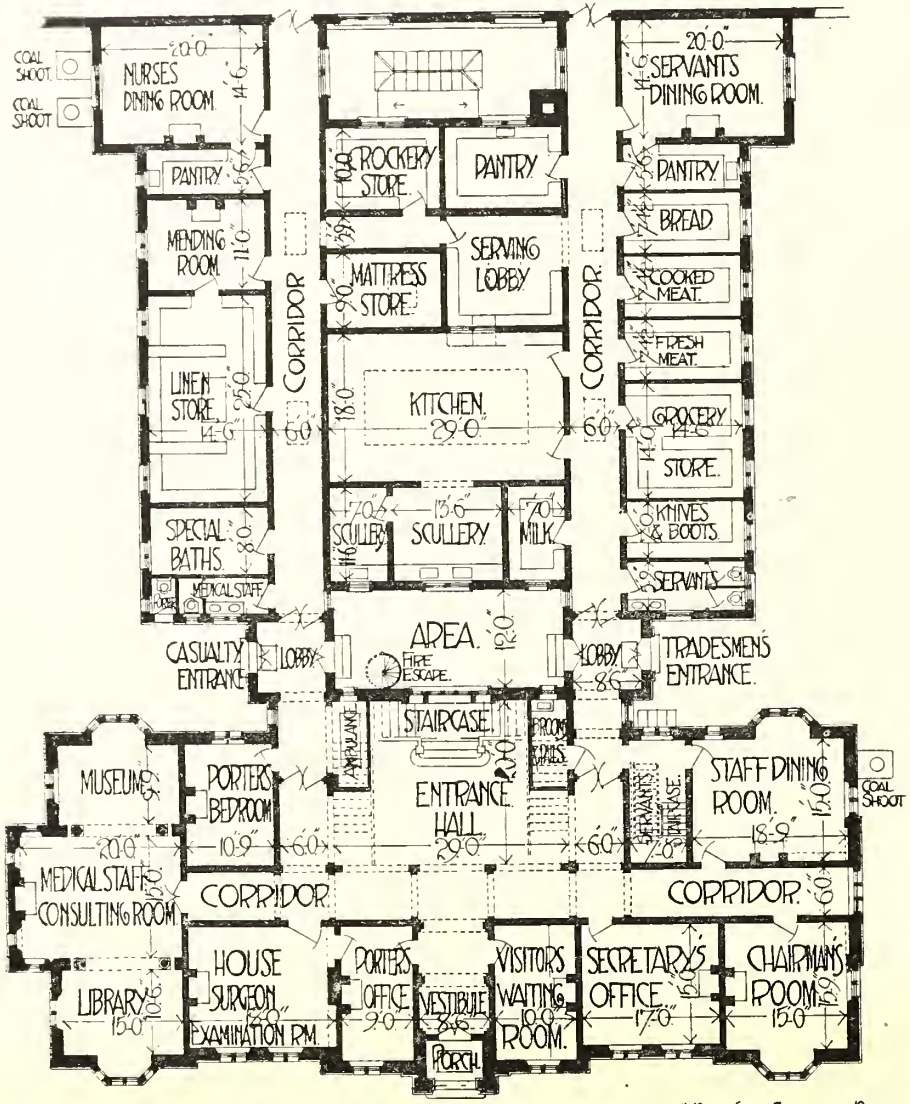
It is generally considered that there should not be more staircases in an hospital than are absolutely necessary. If in a large hospital there be one to every ward-block, the natural result is that doctors and nurses chase one another round and round, however much they may desire to meet. On the other hand, it is not well that a connecting corridor should itself be many storeys in height, and very frequently it occurs only on the ground floor, and the separate staircases, with all their inconveniences, are preferred to multiplying the corridors. In infectious diseases' hospitals, and in fact in all cases where the cost is not prohibitive, it is best to build a hospital of one storey only, but this is an expensive thing to do, and the ward-blocks are frequently two or three and sometimes more storeys in height. In very large hospitals it is necessary that there should be an operating block on each floor, and often on each side of the administration block, one side being reserved for surgical and the other for medical cases, while further subdivision will keep the male wards on one floor and the female wards on another, or otherwise provide for efficient separation. It will be noticed that at Bedford, which is a comparatively small hospital, there is only one male block, one female block, and one children's block, while a single operating block suffices. It is essential to have at least one operating-room on the ground floor, and it should be on the north side and perferably top lighted, so that there may be plenty of light on the operating table. This position is selected also in order to serve accident cases at the earliest possible opportunity, while at Bedford it will be noticed that it is near enough to the out-patients' department for use in case of an emergency in connection with that block.

In a modern hospital lifts are absolute essentials, and should be large enough for the conveyance of a patient on a stretcher or bed, while subsidiary lifts are also useful for the food trolleys. Underneath the connecting corridor there is generally a subway for the conveyance of pipes and wires, and this is also often used in connection with the heating and ventilating appliances

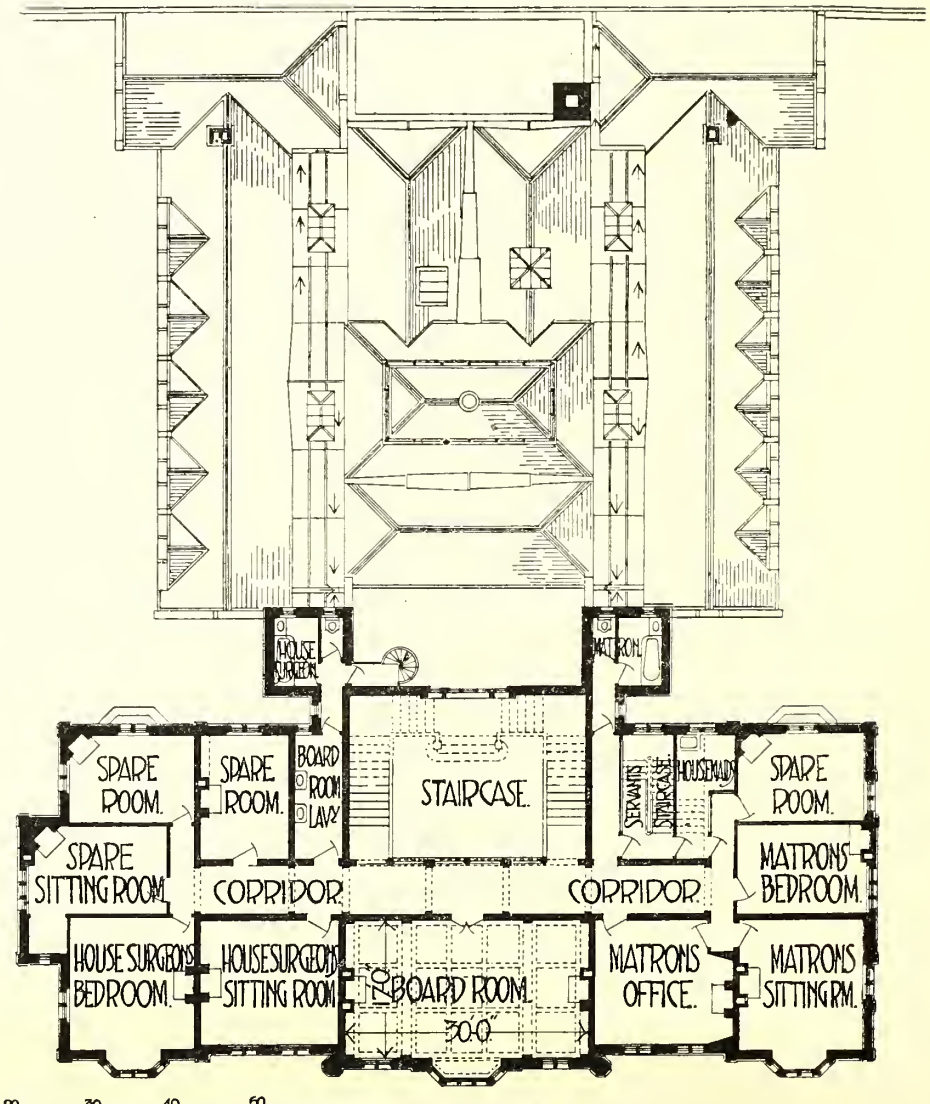
As a matter of detail, but one of some considerable importance, it may be noted that throughout the whole of an hospital there should be no sharp corners. All angles are rounded, even those between floors and walls and walls and ceilings, to say nothing of the panels of doors and the mouldings on window sashes. Everything has to be accessible to a duster, with no places in which dust may lodge, for absolutely spotless cleanliness combined with plenty of sunshine and fresh air are relied upon for the cure of disease to a much greater extend than medicine. It is also perfectly essential that there should be a thorough system of telephonic communication between the wards, the kitchens, the nurses' and matrons' rooms, and the surgeons' rooms, though there are few cases in which this has yet been worked out as thoroughly as it ought to be.

The various portions of this hospital may very well be considered separately in detail, as it is generally acknowledged to be a model for hospitals of moderate size. Fig. 15 consequently illustrates the administrative block. This is symmetrically planned, the entrance being in the centre of the front, through a vestibule, into a large entrance hall, with a fine staircase rising in front having a large staircase window. There is a waiting-room for visitors, and beyond it, entered from a transverse corridor, are the secretary's and chairman's rooms, as well as the staff dining-room with its service entrance from the kitchen corridor. On the other side of the vestibule is the porter's office, the door of which contains an inspection hatch, and the porter has also another door through to the house and the surgeon's examination-room, which can also be reached from the transverse corridor. At this end of the corridor there is a large room for consulting purposes, which contains also a museum and a medical library. It will also be seen that the porter has a bedroom close by, and that under his control is an ambulance which is kept underneath the staircase. Two corridors pass, one on either side of the staircase, into the kitchen department, each traversing the lobby.

BEDFORD COUNTY HOSPITAL.
ADMINISTRATION BUILDING.
H. PERCY ADAMS F.R.I.B.A., LONDON.



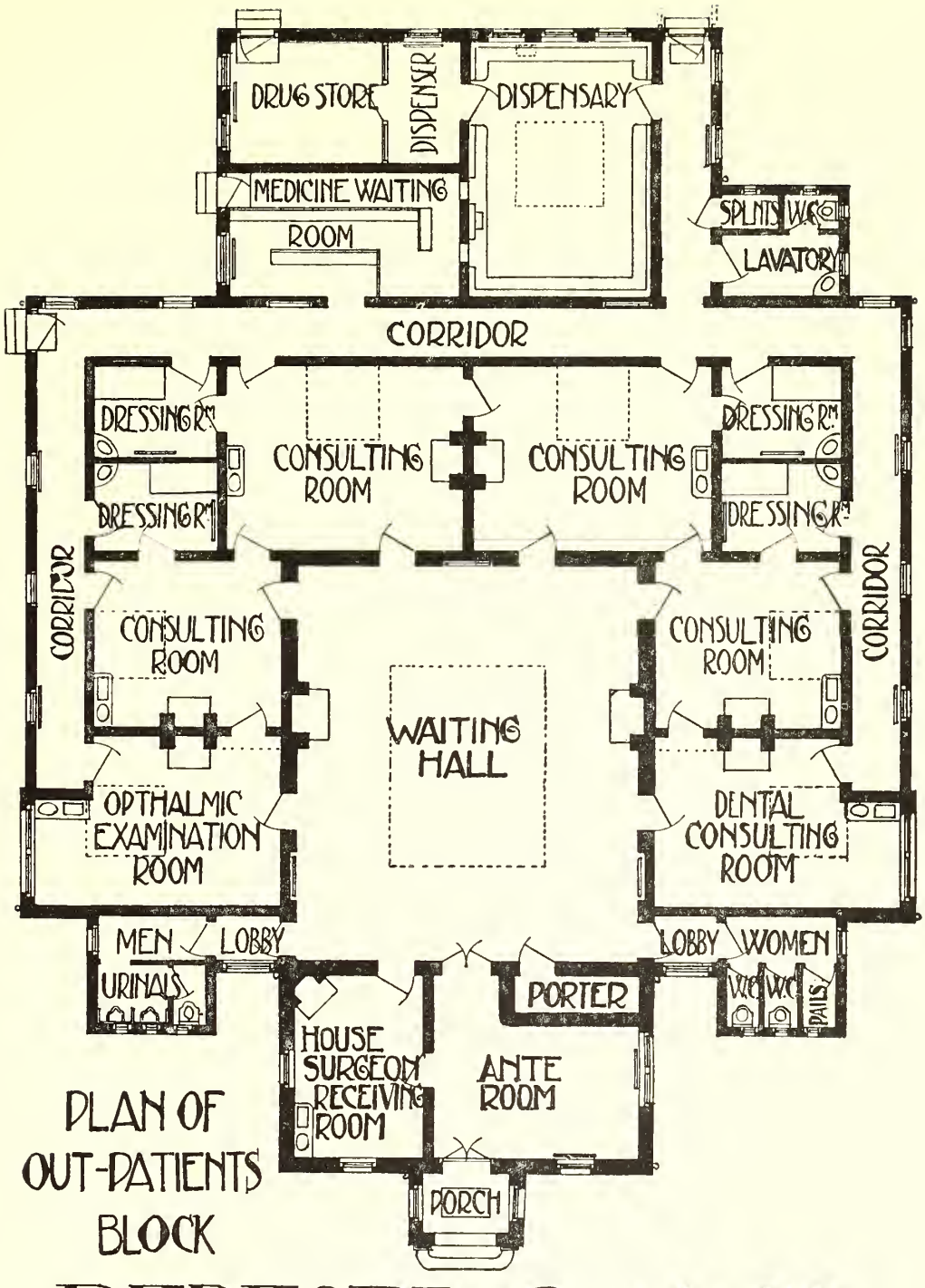
GROUND FLOOR PLAN.



FIRST FLOOR PLAN.

11 10 5 0 10 20 30 40 50
SCALE OF FEET

FIG. 15.



PLAN OF OUT-PATIENTS BLOCK

BEDFORD COUNTY HOSPITAL

H. PERCY ADAMS F.R.I.B.A. ARCHITECT

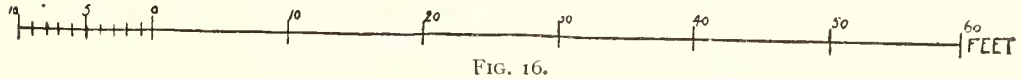


FIG. 16.

One of these serves as a casualty and the other as a tradesman's entrance, and there are doors also leading from each into an internal area, which contains an iron fire-escape staircase as a secondary exit from the floor above in case of fire. On the casualty side there is direct communication from the entrance, either to the house surgeon's examination-room in one direction, or down the corridor to the main communication corridor which leads to the wards, passing a room devoted to special baths on the way, as well as the linen stores and mending-room belonging to the hospital, and the nurses' dining-room, which latter is placed close to the communicating corridor.

The other corridor through the administrative block serves the kitchens. The main kitchen is placed in the centre and is top lighted. It is shown on plan as a bare room, for the cooking would be done entirely by modern appliances without the use of a coal fire. From the kitchen, service, except to the staff dining-room, is made entirely through a hatch to a serving lobby, where the trolleys are loaded and passed forward. The servants' dining-room, like that of the nurses, is close to the communicating corridor, and at that end also are placed the pantries and crockery store, while the food stores are ranged in series on the farther side of the corridor from the kitchen, and are carefully departmented, there being separate stores for bread, for cooked meat, for fresh meat, and for grocery, while a sufficiently large room is also provided for cleaning knives and boots.

The perfection of the departmenting may well be noticed. Thus the kitchen has all kitchen requisites within reach, while perfect service is secured, whether it be to the wards or to the three separate dining-rooms for the medical staff, nurses, and servants. Similarly the linen stores, with the mending-room and the mattress store, are under the control of the nurses. One side is therefore devoted to kitchen use and the other to hospital use, with just sufficient intercommunication for service purposes.

Only the front portion is carried up above the ground floor, and that contains, on the first floor, a large and handsome board-room opposite the staircase, with matron's offices, bedroom, and sitting-room on one side, and similar rooms for the use of the surgeons on the other, each with lavatories and bathrooms properly disconnected. The upper floor is devoted to servants' and nurses' bedrooms. All this is served by a secondary staircase as well as by the main staircase, and this is placed so as to be under the immediate supervision of the matron.

The out-patients' department, illustrated in Fig. 16, is planned somewhat upon the same idea as in the administration block, considerable use being made of top lighting, as it is a single-storey building. Externally it is symmetrical, and internally also to a considerable extent; and it is planned round a centre hall much as the administrative block is planned round the kitchen. The entrance, through a porch and ante-room, leads directly into a large waiting-hall, though a house surgeon's receiving-room is so placed as to command the ante-room. From this hall the various consulting-rooms open, while there are retiring-rooms for men and women on either side, each with proper air disconnection. The exits are quite distinct, nobody passing back to the waiting-room after having once entered the consulting-room. External lighting as well as top lighting is given to the dental-room and the ophthalmic-room, but the ordinary consulting-rooms have top lights only, and there is a small dressing-room in connection with each. These all open to an external corridor, from which patients can pass either direct to the exit or to a covered way leading to the hospital; or else may find their way out through the medicine waiting-room, where they are able to line up, seated on long benches, until they are served through the pigeon holes from the dispensary. The back corridor is also used by the doctors in order to obtain access to the consulting-rooms.

Fig. 17 illustates one of the wards in detail, and although only the ground floor plan is shown, it is practically the same on the first floor. Turning at right angles off the main corridor, a well-lighted staircase is passed, with stores for coals, clothes, and brooms, and a couple of lifts. A square block is thus made up which is separated from the ward block proper by a short passage with folding glass doors on either side for purposes of disconnection. The same branch corridor (which turns to the right off the main corridor) is carried through to the ward, and is of sufficient width for carrying a patient along on a stretcher. In this way it passes a single-bed ward and the ward kitchen on one side, and a larder, linen airing room, and convalescents' dayroom on the other. The ward is a long building planned entirely in accordance with accepted ideas, the beds being ranged along either side, between windows which have high sills *and are carried up to the ceiling level*, while they occur opposite to one another, so as to give a through current of air at all times. These long narrow windows are generally constructed as sashes for the greater part of their height, the upper portion being made as hoppers, opening inwards and shielded at the sides. These are kept almost always open, and are trusted much more for ventilation than any artificial system which may be used. The beds are spaced widely apart, and are placed so that it is possible to get round them on all sides. Wards are always at least 12 feet high, and, while anything above 13 feet is considered as waste space, it is often increased to 14 or even 15 feet for the sake of appearance. In this instance the width is 27 feet, but it is often as little as 22 feet, when, however, the length is proportionately increased so as to secure a sufficient cubical air space per patient. The allowance in general hospitals is usually about 1200 cubic feet per patient, but for wards devoted to infectious diseases

this is frequently raised to as much as 2000 cubic feet. Where the patients are children, however, half of this is frequently considered to be sufficient. At Bedford the warming is effected by means of what are known as Manchester stoves, these being low stoves with table tops which stand in the middle of the ward and have open fires at both ends of them. Air is admitted to them from ducts which pass under the floor, and, passing round outside the casing of the fireplace, it enters the ward in a heated state, while the smoke and other products of combustion are likewise carried down to horizontal flues beneath the floor to chimneys in the outer wall. The necessary cleaning eye for sweeping purposes will be seen upon the plan.

The ward is best placed with its axis running north and south, the entrance corridor lying at the north end of the block, and the south end being devoted to a window from which the ward can be overlooked by the nurses, while the dayroom, which has a bay window for the sake of sunshine, is also under supervision by means of windows from the corridor. Of course, it will be understood that no cooking is actually done in this kitchen, which is used only for keeping food warm and for washing up the ward crockery, which is never allowed to go outside the block. The little larder here, too, is not intended in any way to take the place of the general larders. It is more for the temporary storage of such things as jellies, milk, and beef-tea, especially in order to keep them cool during hot summer days. Its window consequently faces north.

Fig. 18 illustrates the Royal Naval Hospital at Chatham, designed by Mr. J. C. T. Murray, F.R.I.B.A., which is in its main idea similar to the hospital at Bedford, for both are good examples of a general

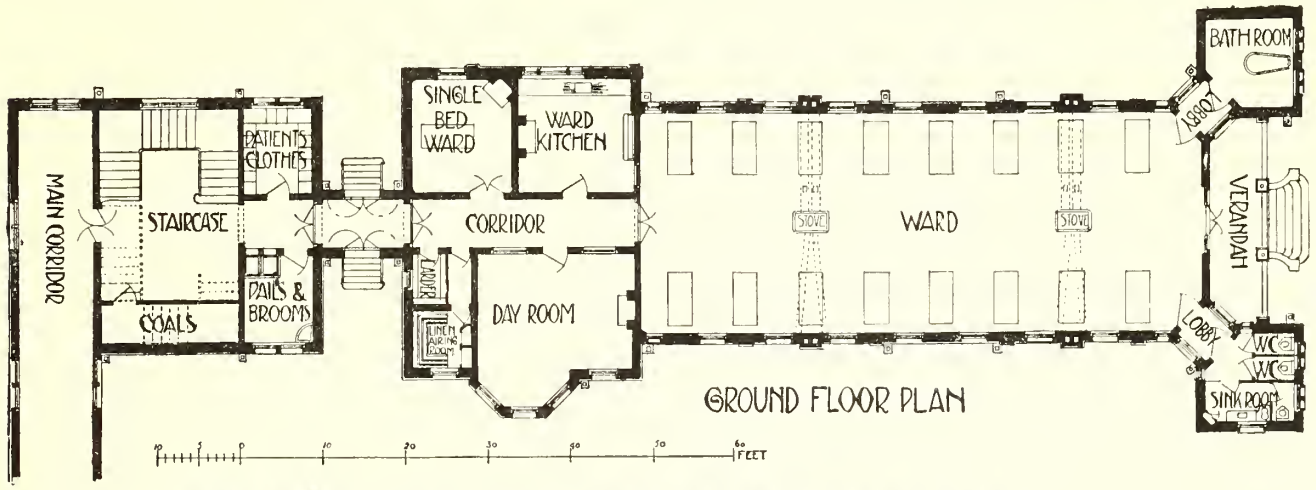


Fig. 17.

verandah on to which patients can be wheeled on sunny days to take advantage of the fresh air and sunlight. This is flanked on one side by a tower containing the bathrooms, and on the other by a similar tower with the W.C.'s, slop sinks, etc., both of these being disconnected by the usual cross current of ventilation. A small ventilated cupboard is provided in the sinkroom for keeping bedpans prior to inspection of their contents by the medical staff. The bath, it will be noticed, stands in the middle of the room, so that the nurses can get round it, and very frequently it is upon wheels, so that it can be taken when necessary to the patient's bedside after having been filled. It is thus necessarily made of some light material, preferably of enamelled copper. When it is fixed, however, there is a preference for making it of glazed stoneware.

It will be noticed that the ward kitchen has a small scheme which is now rarely departed from. It is, however, worth illustrating, to show how the generally accepted plan has to be varied in order to meet special circumstances. There is here no need for an out-patients' block, as in-patients only would be treated. Almost all the nursing is done by men, but this does not call for any great alterations in the plan. The main entrance occurs, as is usual, through a central corridor, passing first through an administration block, and leading subsequently to a kitchen block from which the great transverse connecting corridor diverges on either side. The ward blocks are again at right angles to this, but are found on both sides of it, particularly at its extreme ends, while special small blocks occur as recreation-rooms, and others as small special wards for ophthalmic patients and for the warrant officers, the latter when in hospital each having a separate room. The south portion of the site is covered

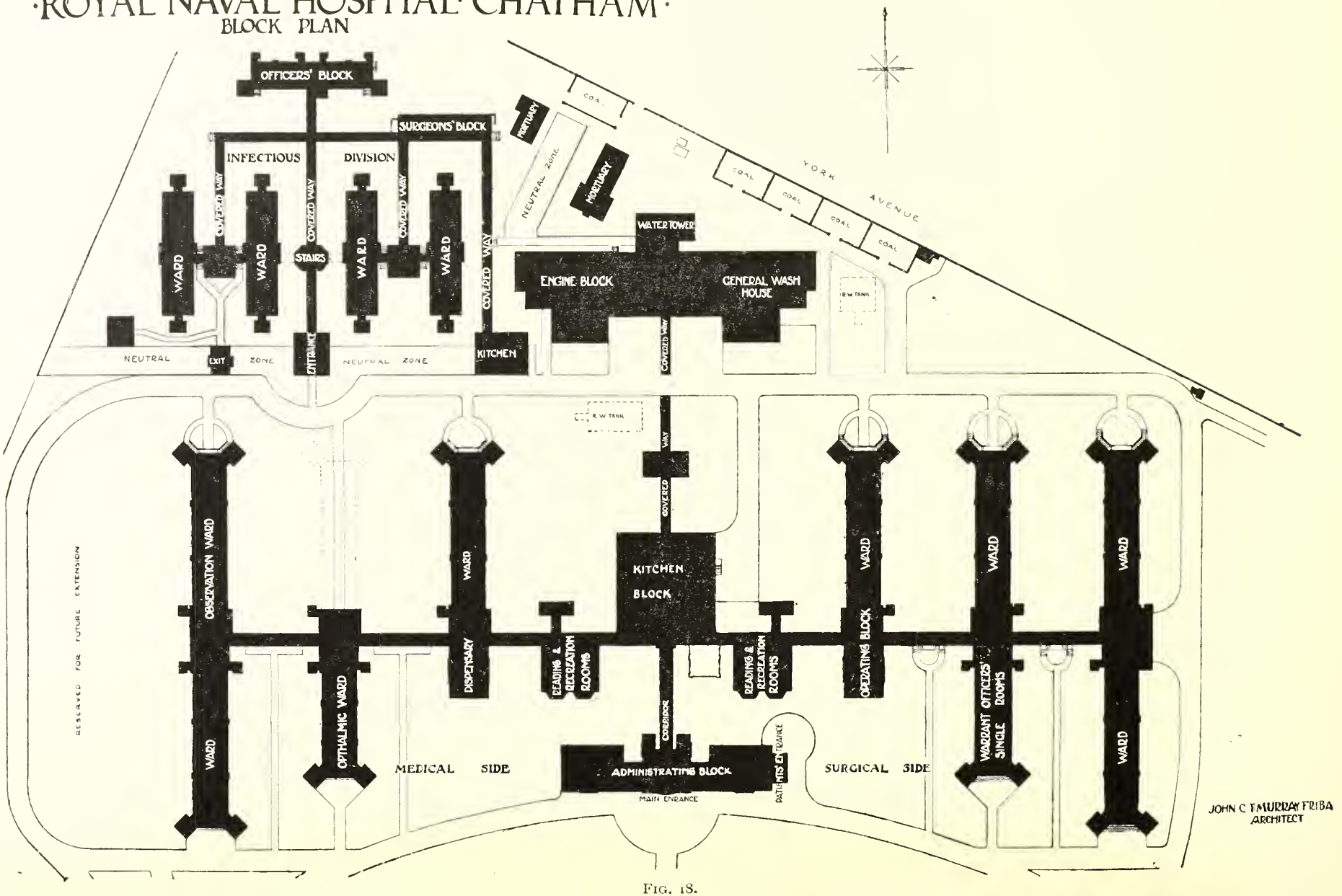
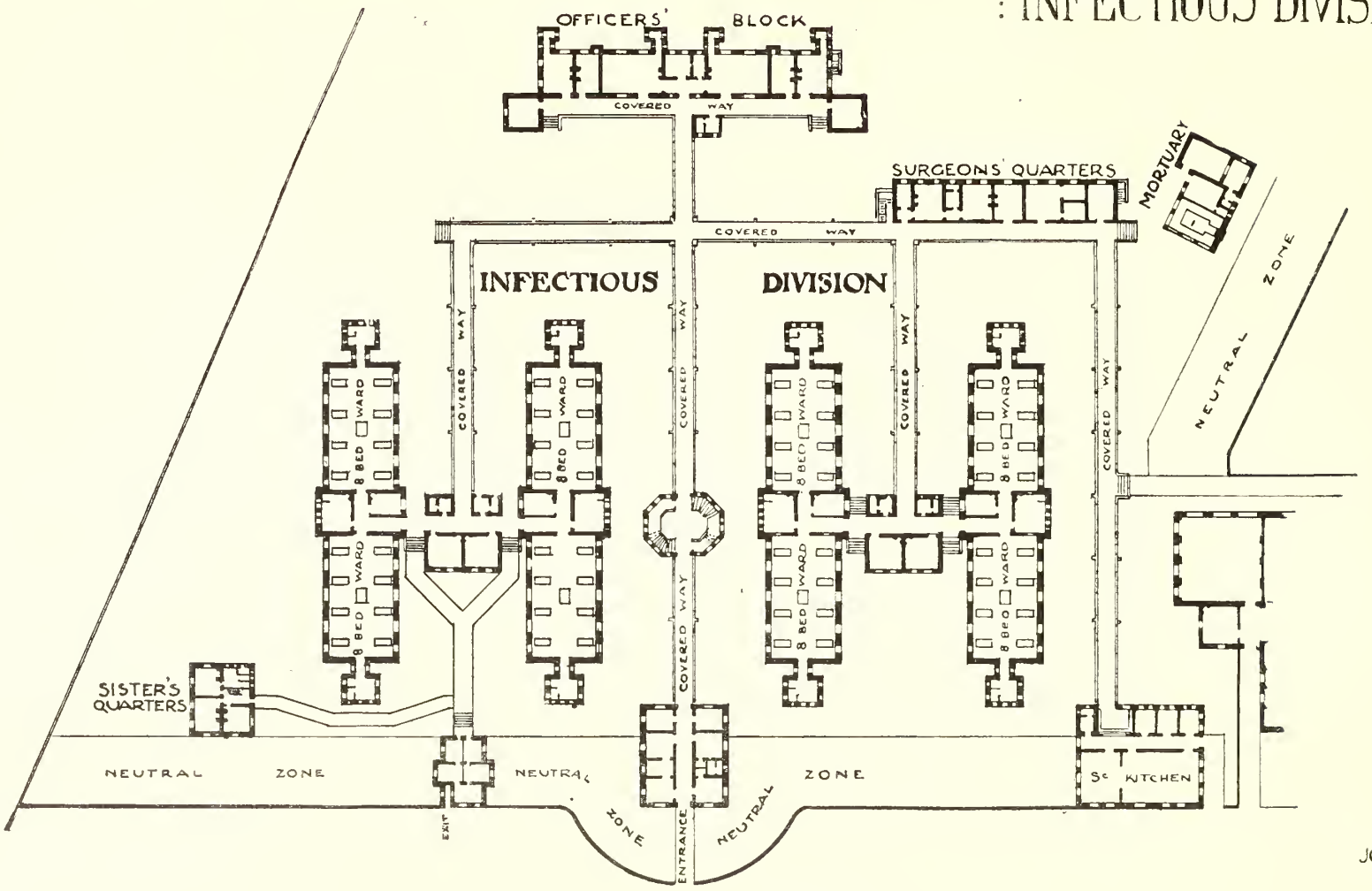

·ROYAL NAVAL HOSPITAL· CHATHAM·
BLOCK PLAN
OFFICERS' BLOCK
SURGEONS' BLOCK
INFECTIOUS DIVISION
COVERED WAY
WARD
STAIRS
MORTUARY
NEUTRAL ZONE
COAL
YORK AVENUE
WATER TOWER
ENGINE BLOCK
GENERAL WASH HOUSE
R.W. TANK
NEUTRAL
EXIT
ZONE
HYDRANT
KITCHEN
OBSERVATION WARD
OPTHALMIC WARD
DISPENSARY
READING & RECREATION ROOMS
KITCHEN BLOCK
CORRIDOR
OPERATING BLOCK
WARRANT OFFICERS' SINGLE ROOMS
MEDICAL SIDE
SURGICAL SIDE
ADMINISTRATING BLOCK
MAIN ENRANCE
PATIENTS' ENTRANCE
RESERVED FOR FUTURE EXTENSION
JOHN C MURRAY FRIBA
ARCHITECT

FIG. 18.

·ROYAL NAVAL HOSPITAL· CHATHAM·

: INFECTIOUS DIVISION :



JOHN C T. MURRAY F.R.I.B.A.
ARCHITECT

FIG. 19.

in this way, and devoted to a general hospital, which is surrounded by a carriage way, beyond which again and in direct line with the entrance corridor is found a large block devoted to the engines and dynamos, and to a washhouse. Behind this block, and well screened, is the principal mortuary, which in detail is divided into several parts, one being devoted to post-mortems, and another having a viewing room for use at inquests. The north-west corner of the site is given up to an infectious division, separated from the general hospital by a neutral zone covered with trees, its kitchen, its entrance, and its exit alone being accessible from the main hospital.

This is shown in greater detail in Fig. 19, where the kitchen appears as an entirely detached block, connected

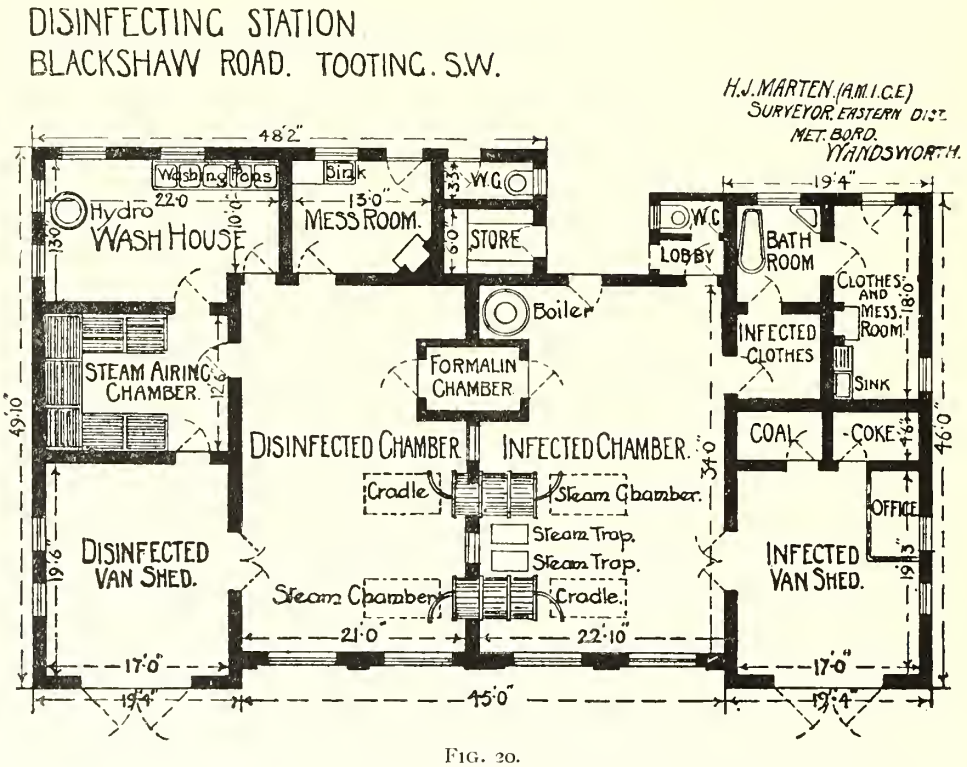


Fig. 20.

with the wards only by a long covered way, which the kitchen servants never enter, the food being served through a hatchway on to tables in the waiting-room, whence it is fetched away by the nursing staff. The surgeons' quarters are located alongside the covered way, so that they also are disconnected. The entrance is in the centre, through a small detached block containing waiting-rooms, and a few small observation wards for single patients, where any cases can be retained about which there is doubt until the disease fully develops. A central covered way passes from this block through a staircase block, by means of which, on the upper floors, the two central wards are reached by bridges. In this way the central wards are coupled on the upper floor, whereas they are detached on the ground floor where the outer wards are coupled. Between each of these pairs of blocks there are single-bed wards, while the general wards contain eight beds each, and are planned very similarly to the wards of the Bedford Hospital, with the exception that there is no end verandah and only a single sanitary block to each ward. It may here be mentioned that, in the general portion of the hospital, the beds are not so greatly separated as they are at Bedford, but are placed in pairs along the wards.

A special provision has to be made at Chatham for officers, who have a separate block devoted to them in the infectious division. As a rule officers are not treated in the general hospital, as, except in cases of accident, they go home when taken ill, but of course when they are suffering from anything infectious they are removed at once to the hospital, and there they have to be kept distinct from the men. As far as possible they would be given single-bed wards, but not necessarily so. The great object in an infectious hospital is to have ample air space and plenty of sunshine, and this is obtained. There is a covered way along the south side of the officers' block, where patients could be taken out in good weather.

The nursing sisters are provided with a special little block of their own, quite distinct from anything else, while in another part of the ground, close to the other mortuary, occurs the infected mortuary, again with visitors' room and viewing-room.

Every hospital of any size is equipped with a complete laundry with a special arrangement for disinfection of the clothing. The disinfecting station belonging

to the Wandsworth Borough Council at Tooting, shown in Fig. 20, and designed by Mr. H. J. Marten, A.M.Inst.C.E., is an example of the sort of thing, although the washhouse is not here so complete in its detail as it would be in the case of a hospital. A borough installation of this sort is primarily intended for disinfection, and washing is comparatively rarely necessary. Into such a building are taken all the clothes, bed hangings, and everything else of a portable nature, other than actual furniture, from the rooms in which a case of infectious disease has occurred. The goods are brought in closed vans, entering what is here known as the infected van-shed, containing an office for record. The van is here emptied, and the goods are passed into the infected chamber, whence they are transferred either to the steam disinfectors or to the formalin chamber according to their nature, all goods which will not be damaged by steam being steam treated. After remaining in these chambers for a sufficient period of time, the farther door is opened and the goods are taken out into the disinfected chamber, and, as a rule, passed direct to the van in which they are taken home, though in some cases they have to go first through the washhouse and the steam-drying or airing chamber. Only rough washing is attempted, as there is no obligation upon the borough council to properly get up linen, etc., and as a result there are no ironing or sorting rooms. It will be seen that the attendants on the two sides do not come into contact with one another, and that those who manage the infected clothing have to pass through a bathroom and to change their clothes on their way in and out.

This bathroom arrangement is also found in infectious diseases hospitals at the patients' exit, which generally contains waiting-rooms for the patients' friends on the outer side. Each patient is taken in turn to a dressing-room, undressed, then given a medicated bath to secure thorough disinfection, and afterwards carried, as a rule wrapped in blankets, across an open passage to another dressing-room, where the ordinary clothes brought by the friends are put on.

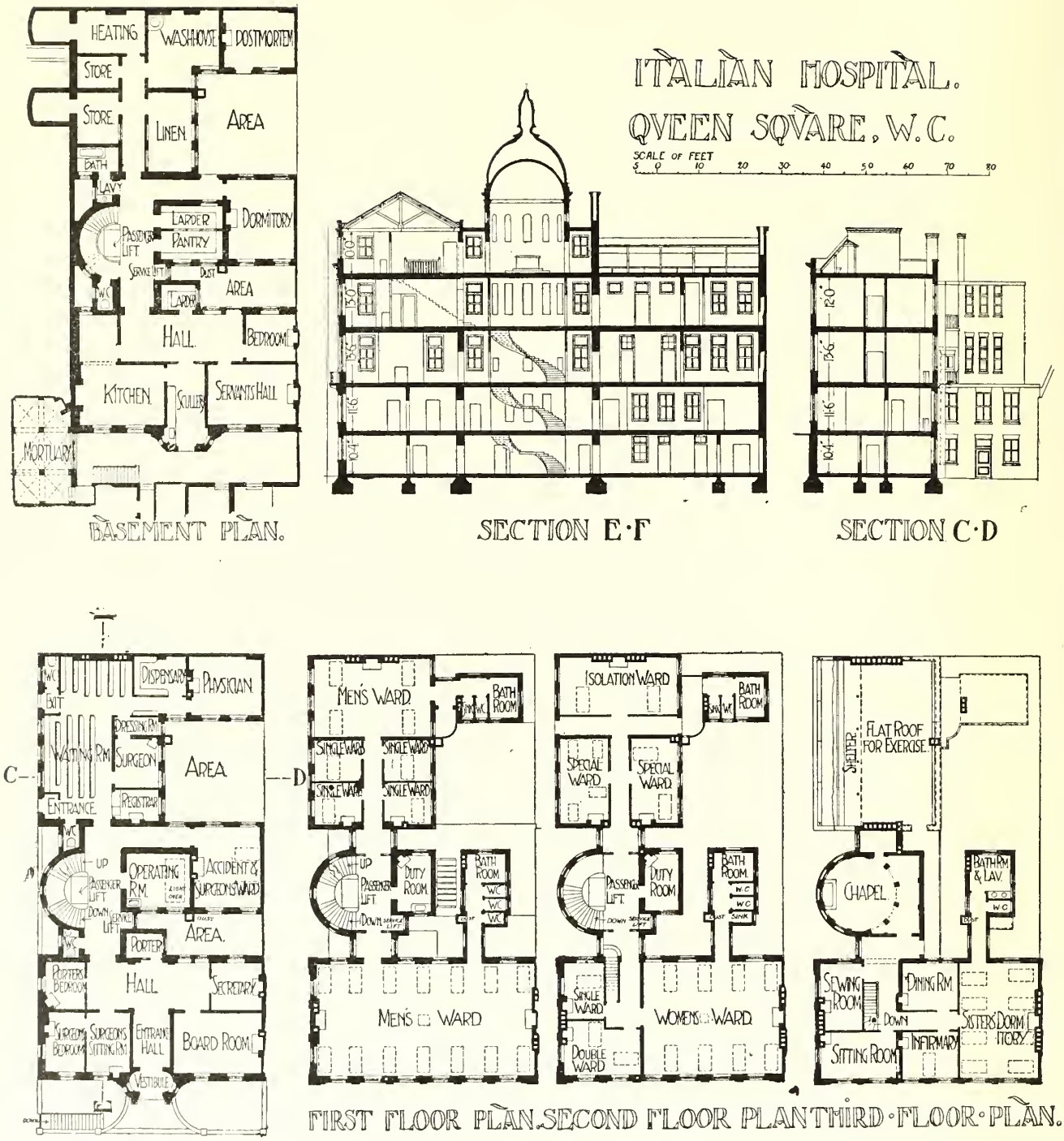

ITALIAN HOSPITAL.
QUEEN SQUARE, W.C.
SCALE OF FEET
5 0 10 20 30 40 50 60 70 80
HEATING
WASHHOUSE
POSTMORTEM
STORE
STORE
LINEN
AREA
BATH
LAVY
LARDER
PANTRY
DORMITORY
PASSENGER LIFT
SERVICE LIFT
DUST
W.C.
LARDER
AREA
HALL
BEDROOM
KITCHEN
SCULLERY
SERVANTS HALL
MORTUARY
BASEMENT PLAN.
SECTION E·F
SECTION C·D
C
D
E
F
WC
EXIT
DISPENSARY
PHYSICIAN
WAITING RM
DRESSING RM
SURGEON
AREA
ENTRANCE
REGISTRAR
UP
PASSENGER LIFT
DOWN
SERVICE LIFT
OPERATING R.M.
LIGHT OVER
ACCIDENT & SURGEON'S WARD
DUST
AREA
PORTER
PORTER'S BEDROOM
HALL
SECRETARY
SURGEON'S BEDROOM
SURGEON'S SITTING RM
ENTRANCE HALL
BOARD ROOM
VESTIBULE
DOWN
GROUND FLOOR PLAN.
MEN'S WARD
BATH ROOM
SINGLE WARD
SINGLE WARD
SINGLE WARD
UP
PASSENGER LIFT
DOWN
SERVICE LIFT
DUTY ROOM
BATH ROOM
W.C
W.C
W.C
MEN'S WARD
ISOLATION WARD
BATH ROOM
SINK
W.C
SPECIAL WARD
SPECIAL WARD
PASSENGER LIFT
DOWN
SERVICE LIFT
DUTY ROOM
BATH ROOM
W.C
W.C
SINK
SINGLE WARD
WOMEN'S WARD
DOUBLE WARD
SHELTER
FLAT ROOF FOR EXERCISE
CHAPEL
BATH RM & LAV.
W.C
SEWING ROOM
DINING RM
DOWN
SISTER'S DORMITORY
SITTING ROOM
INFIRMARY
FIRST FLOOR PLAN.
SECOND FLOOR PLAN
THIRD·FLOOR·PLAN.
THOMAS. W CUTLER
ARCHITECT

FIG. 21.

CHAPTER VII

HOSPITALS ON RESTRICTED SITES

When hospitals have to be built in crowded cities and upon comparatively small pieces of land, a good deal of skill is necessary in order to obtain the accommodation in compliance, to as great an extent as possible, with the rules already discussed. Considerations of aspect, important as they are, have to give way before the greater consideration of an ample supply of air to the wards ; and these, instead of being ranged far apart with wide spaces between them, and themselves of only one or two storeys in height, have to be piled up on top of one another, more or less obstructing light and air to all parts of the building. Obstruction of some sort being unavoidable, it is consequently essential that the wards should have the first consideration, and the administrative offices and kitchens are consequently placed as a general rule on the lower floors, the kitchens often extending over the whole area, and being to a considerable extent top lighted and flat roofed, while just the ward portions are carried up.

Under these conditions, varying as they do in every case, it is hardly possible to develop a definite type, and all that can be done here satisfactorily is to give a few examples, differing from one another in point of surrounding circumstances as much as may be. In Fig. 21 is illustrated the Italian Hospital built in Queen Square, Bloomsbury, from the design of Mr. T. W. Cutler, F.R.I.B.A., on a narrow corner site, having the main entrance necessarily upon the short frontage. As in most such cases, the planning was controlled more by the wards than by the ground floor, the principal wards occurring upon the narrow frontage and extending over the whole width. It is thus, perhaps, desirable to consider the first-floor plan before that of the ground floor, and here, in the principal position, we find the men's ward so contrived. The normal arrangement of opposite windows, and windows between the beds, has been possible except in two places, where windows are replaced by doors, the only departure from the customary arrangement being the placing of fireplaces at the two ends of the ward, and the omission of the sunning balcony, for which there was no room ; while the usual sanitary annexe has been obtained at the back, in such a position as to obstruct the passage of air to a comparatively small extent. The duty-room, too, is separated from the ward by an area for light, but it is sufficiently near for most practical purposes, and has a window which overlooks two of the ward windows, thus securing a certain amount of supervision. There are the usual disconnection passages, and access is obtained by means of a semicircular staircase and a lift in the well hole, besides a small service lift at the side. In addition to this ward in the front, there are others at the back of the building, which could, had it been thought desirable, have been thrown into one, though, owing to the class of patients which had to be provided for, it was thought better to cut up the space into four single wards and a ward of four beds.

The second floor is also devoted to ward purposes, being mainly intended for the use of women ; but the large ward in the front is in this case replaced by a ward for eight beds, and two small ones, one containing two beds and the other a single bed. Disconnection is obtained as on the floor below, and so is communication with the other floors. The back portion is somewhat curiously planned, with two special wards of equal size, one containing two beds for adults, and the other four beds for children, both having glazed partitions so that they can be overlooked from the corridor ; while there is an isolation ward at the extreme end, cut off by a long disconnecting passage having a current of air passing through it. Above this back portion there is a flat roof for exercise, which could be used by convalescents or by such patients as could be carried up there on stretchers, though unfortunately the passenger lift does not go up so far, for on the third floor the space occupied below by the semicircular staircase is taken up by a small chapel.

The front portion of the building is, on the third floor, divided into a series of rooms for the nurses, including a dormitory, dining-room, sitting-room, infirmary, and sewing-room. The infirmary contains only a single bed, and is evidently intended for use during temporary indisposition only.

From all these floors there is a dust shoot to an area in the basement, it being intended to heat the building to a large extent by ordinary open fires.

Turning now to the ground floor, it will be found that the space under the men's ward is given up to a good entrance and hall, out of which board-room, secretary's office, and surgeon's room are reached, as well as a small porter's office and porter's bedroom. Access from the entrance to the passengers' lift and main staircase is quite easy, past both the porter's office and the surgeon's room, the same method of departmenting being followed here as in the Bedford

County Asylum, the secretary's office being near the board-room, and neither being necessarily passed by any patients. The operating-room is obtained underneath the duty-rooms, but it is larger than these, and so obtains top lighting. Its door is immediately opposite the passenger lift, so that there need be no delay in carrying patients to their wards, though unfortunately space is so restricted that no anæsthetic or preparation-room is provided. A small accident ward, however, occurs on this floor, placed in the quietest position which could have been found, behind the operating-room, from which it could be easily reached. There is also access at this point to an out-patients' department, which, though small, is perfectly complete, with separate entrance and exit and a very large waiting-room, and with registrar's office and consulting-rooms both for surgeons and physicians, with the necessary surgeon's dressing-room and physician's dispensary.

Below this floor again is a basement, reached externally by stairs in an area, which passes across the narrow front of the building, and has a mortuary at one end of it in the form of an excavated cellar. The kitchen entrance is also in the middle of this sunk area. The kitchens, servants' hall, and scullery are in the front portion, with a servants' bathroom close to the servants' hall and underneath the secretary's office. There is also a dormitory underneath the accident ward. The larder accommodation, if not extensive, would be sufficient in a city where food is easily procurable, and upon a small site is as much as it has been possible to obtain. There is a small room for a heating apparatus, and also a small washhouse and linen-store, but probably the greater part of the washing would be sent out, as is usually done in London.

The English Hospital at Constantinople, designed by Mr. H. Percy Adams, F.R.I.B.A., is an example of exceedingly skilful and unusual planning upon an awkward site, under climatic conditions demanding that as much air as possible should be admitted to the building, while a central tower was desirable for purposes of effect. The general scheme is that of three wards radiating from a large twelve-sided centre, up which the principal staircase and lift are carried. The principal ward floor, which controls the planning more than any other, is the second floor, shown in Fig. 22. The wards here are intended for the use of sailors. Each contains eight beds, the two principal wards having attached to them a single-bed ward each. Two of the wards have ward kitchens, but their place is taken by a linen-store in the third instance. The two front wards have airing balconies extending along the whole of one side, and reached by patients either in the large ward or in the single ward. All usual means of disconnection are adopted, there being little difference between the arrangement on this floor and that found in an ordinary English hospital in this respect, while the wards are warmed as they would be in England by large Manchester grates. There is a small dayroom also on this floor for the use of the convalescents.

On the third floor (see Fig. 23) only the two front blocks are carried up, and are devoted to bedrooms for the matron and nursing staff, each having her own separate room, while the fourth floor (see Fig. 24) is different from anything which would be found in a cooler country, consisting of flats over the large ward blocks, which are themselves roofed over but open on almost all sides, thus providing large airing balconies sheltered from the sun. These are reached both by the main staircase and the lift, by means of which patients can easily be carried up, and by a small staircase from the nurses' bedrooms. Small shelters are also provided which might form private reading rooms for convalescents, and there is an open gallery round the tower. This central portion is carried up to a considerably greater height, as shown in the small plans of the fifth, sixth, seventh, and eighth floors. By adoption of the large open-roofed balconies, advantage is taken of the climate to give patients the greatest possible amount of fresh air.

It is now interesting to trace the plan downwards. The first-floor plan (Fig. 25) shows that each of the front blocks is here cut up into a number of small single-bed wards, with matron's room, dayroom, ward kitchen, and nurse's room, providing for proper attendance; for in such a city as Constantinople the European population, other than sailors, requiring hospital treatment would be such as to demand attention in separate rooms rather than large wards. Each of these wards has a separate fireplace, and the way in which these have been provided is worth a good deal of attention. The third ward-block, that at the back, is given up to a complete series of rooms devoted to operations, there being the usual disconnecting lobby leading to an inner hall and reached immediately from the lift doors. Out of this inner hall there is an anæsthetic-room and a dressing-store, while the operating-room is only reached through the anæsthetic-room, out of which a recovery ward also opens. This operating-room extends somewhat farther than does the ward above it, the outer wall of which is carried by a girder, and thus the necessary top light to the operating table is obtained. This room is large and very completely fitted, having a scullery attached to it.

The ground floor is shown in Fig. 26, and illustrates the awkward shape of the site upon which the building had to be placed. The entrance is planned between the two main front ward-blocks, and is so schemed that, leading directly into a central tower, it should have an exceedingly handsome and eastern effect. The radiating wards above produce, on this floor, a very simple scheme of departmenting, the space in one of the ward-blocks being devoted to the nurses' dining-

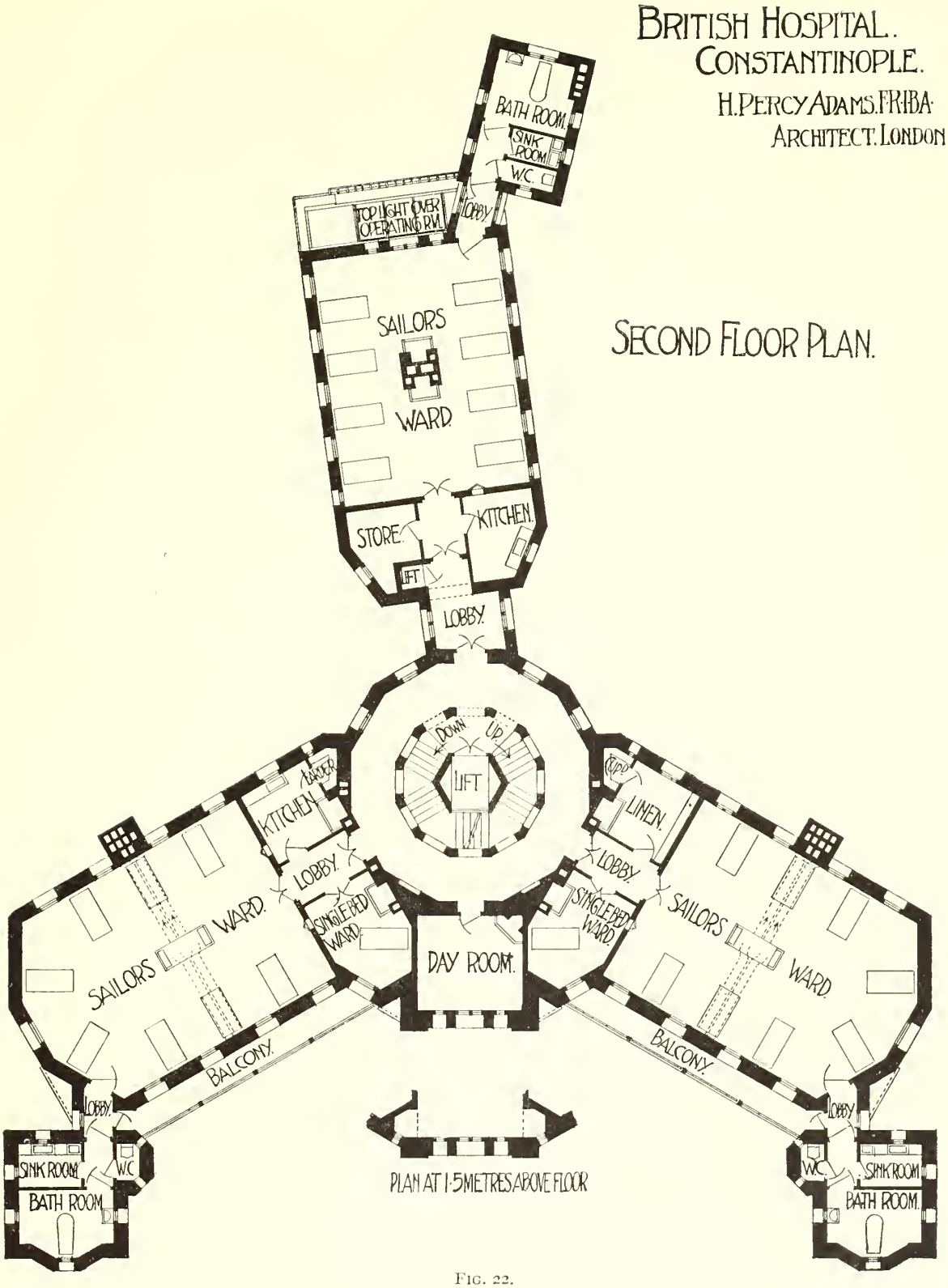

BRITISH HOSPITAL.
CONSTANTINOPLE.
H. PERCY ADAMS. F.R.I.B.A.
ARCHITECT. LONDON.
SECOND FLOOR PLAN.
BATH ROOM.
SINK ROOM.
W.C.
TOP LIGHT OVER OPERATING R.M.
LOBBY.
SAILORS
WARD
STORE.
KITCHEN.
LIFT.
LOBBY.
DOWN
UP
LIFT
LINEN.
LOBBY.
SINGLE BED WARD.
DAY ROOM.
SINGLE BED WARD.
LOBBY.
KITCHEN.
LOBBY.
SAILORS
WARD.
SAILORS
WARD.
BALCONY.
BALCONY.
LOBBY.
SINK ROOM.
W.C.
BATH ROOM.
LOBBY.
W.C.
SINK ROOM.
BATH ROOM.
PLAN AT 1·5 METRES ABOVE FLOOR

FIG. 22.

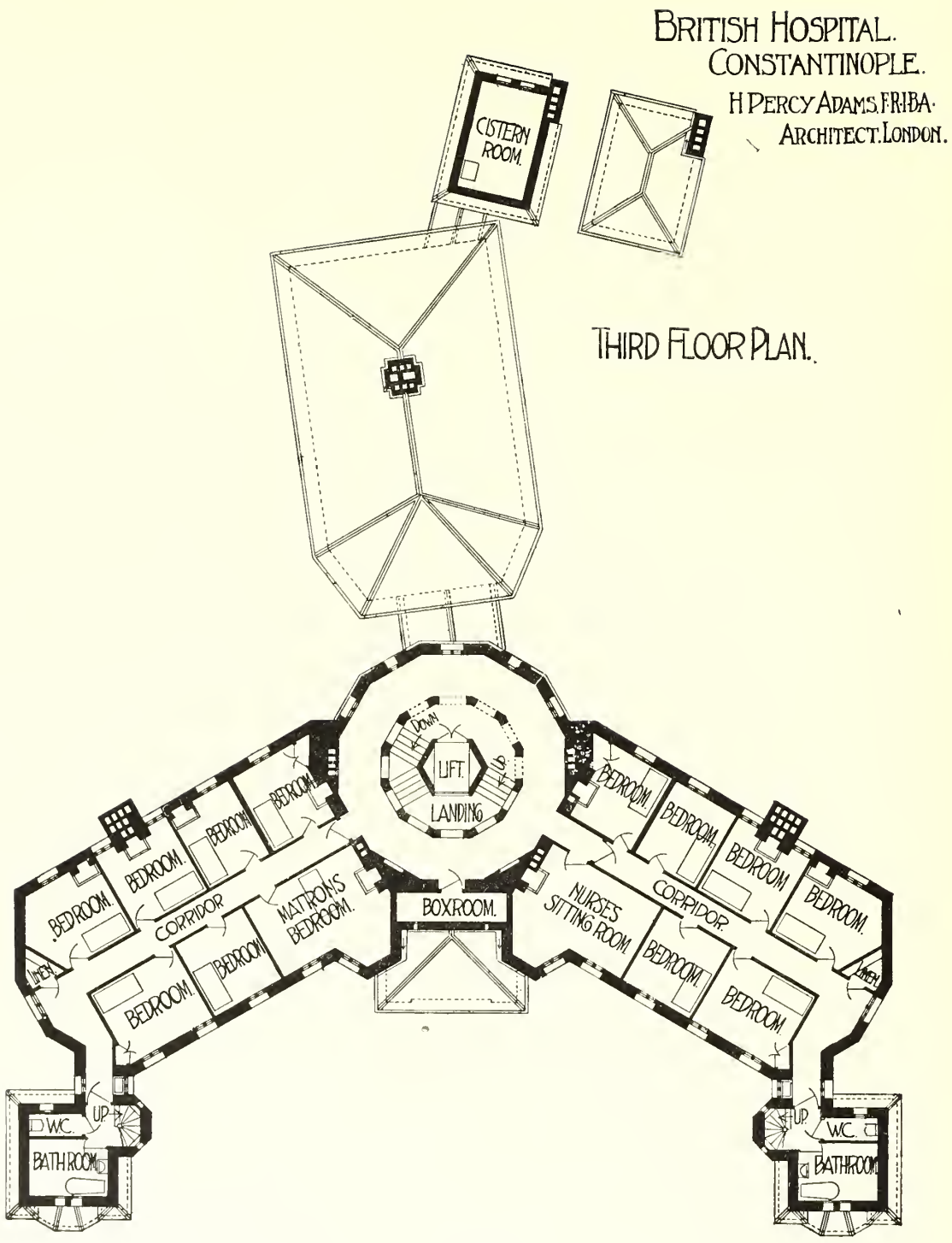

BRITISH HOSPITAL.
CONSTANTINOPLE.
H PERCY ADAMS, F.R.I.B.A.
ARCHITECT. LONDON.
CISTERN ROOM.
THIRD FLOOR PLAN.
DOWN
LIFT.
UP
LANDING
BEDROOM.
CORRIDOR
MATRON'S BEDROOM.
BOX ROOM.
NURSES SITTING ROOM.
LINEN
W.C.
BATH ROOM.
UP

Fig. 23.

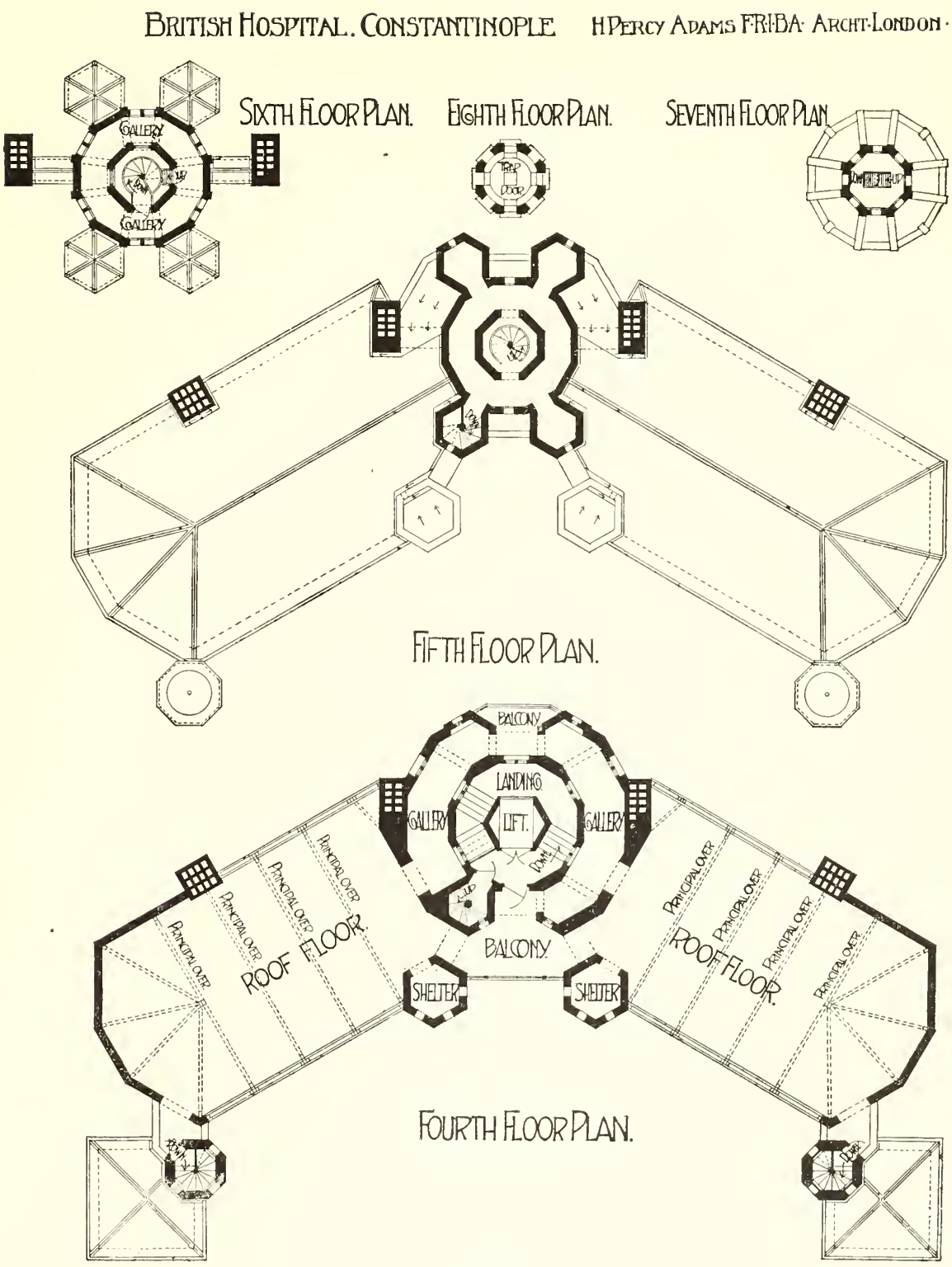
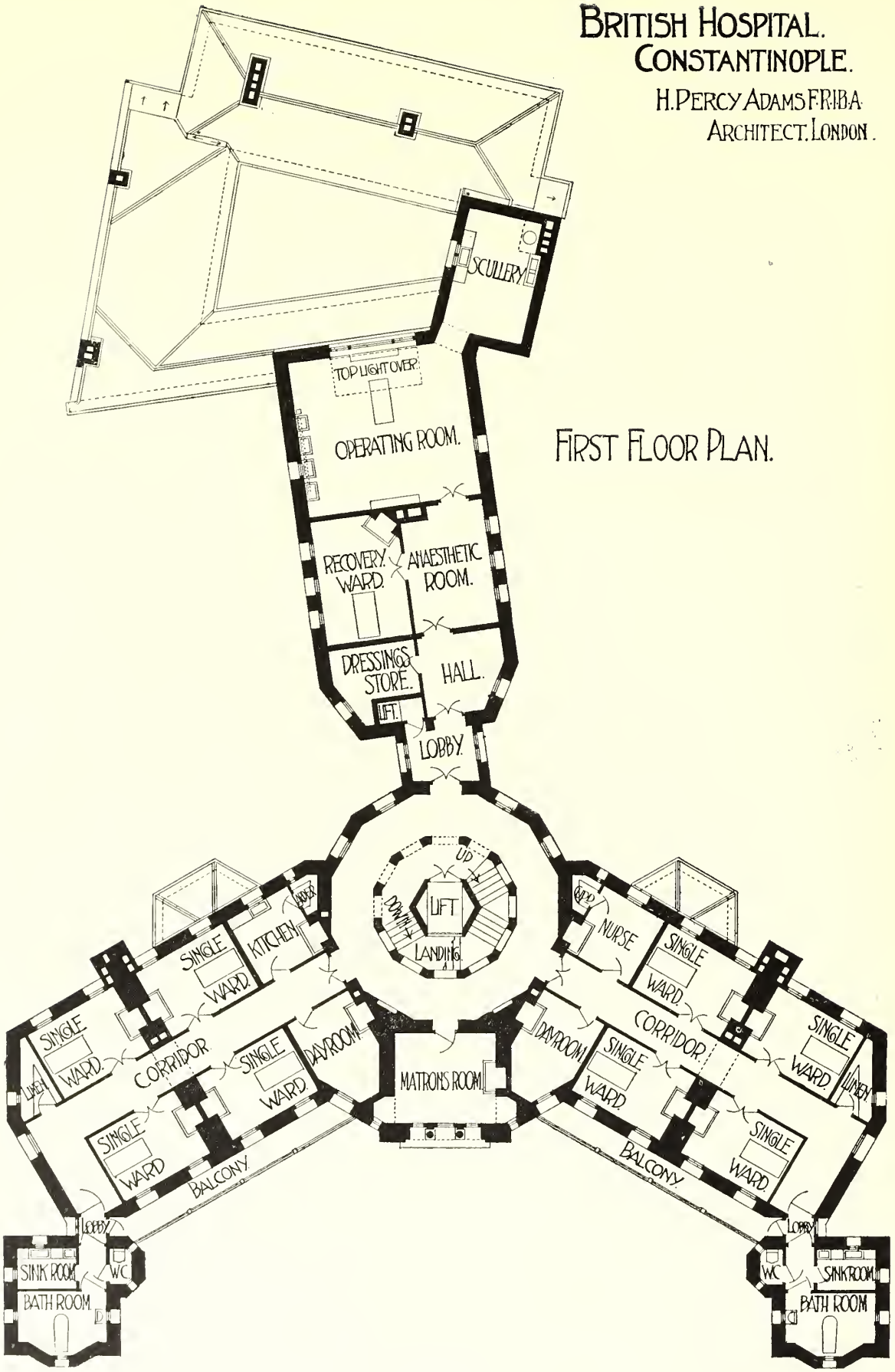

BRITISH HOSPITAL. CONSTANTINOPLE H PERCY ADAMS FRIBA. ARCHT. LONDON.
SIXTH FLOOR PLAN.
EIGHTH FLOOR PLAN.
SEVENTH FLOOR PLAN.
GALLERY
GALLERY
TRAP DOOR
DOMESTIC LIFT
FIFTH FLOOR PLAN.
BALCONY
LANDING
GALLERY
LIFT.
GALLERY
DOME
PRINCIPAL OVER
PRINCIPAL OVER
PRINCIPAL OVER
ROOF FLOOR
BALCONY
SHELTER
SHELTER
PRINCIPAL OVER
PRINCIPAL OVER
PRINCIPAL OVER
PRINCIPAL OVER
ROOF FLOOR
FOURTH FLOOR PLAN.

FIG. 24.

BRITISH HOSPITAL. CONSTANTINOPLE.

H. PERCY ADAMS F.R.I.B.A. ARCHITECT. LONDON.



FIRST FLOOR PLAN.

FIG. 25.

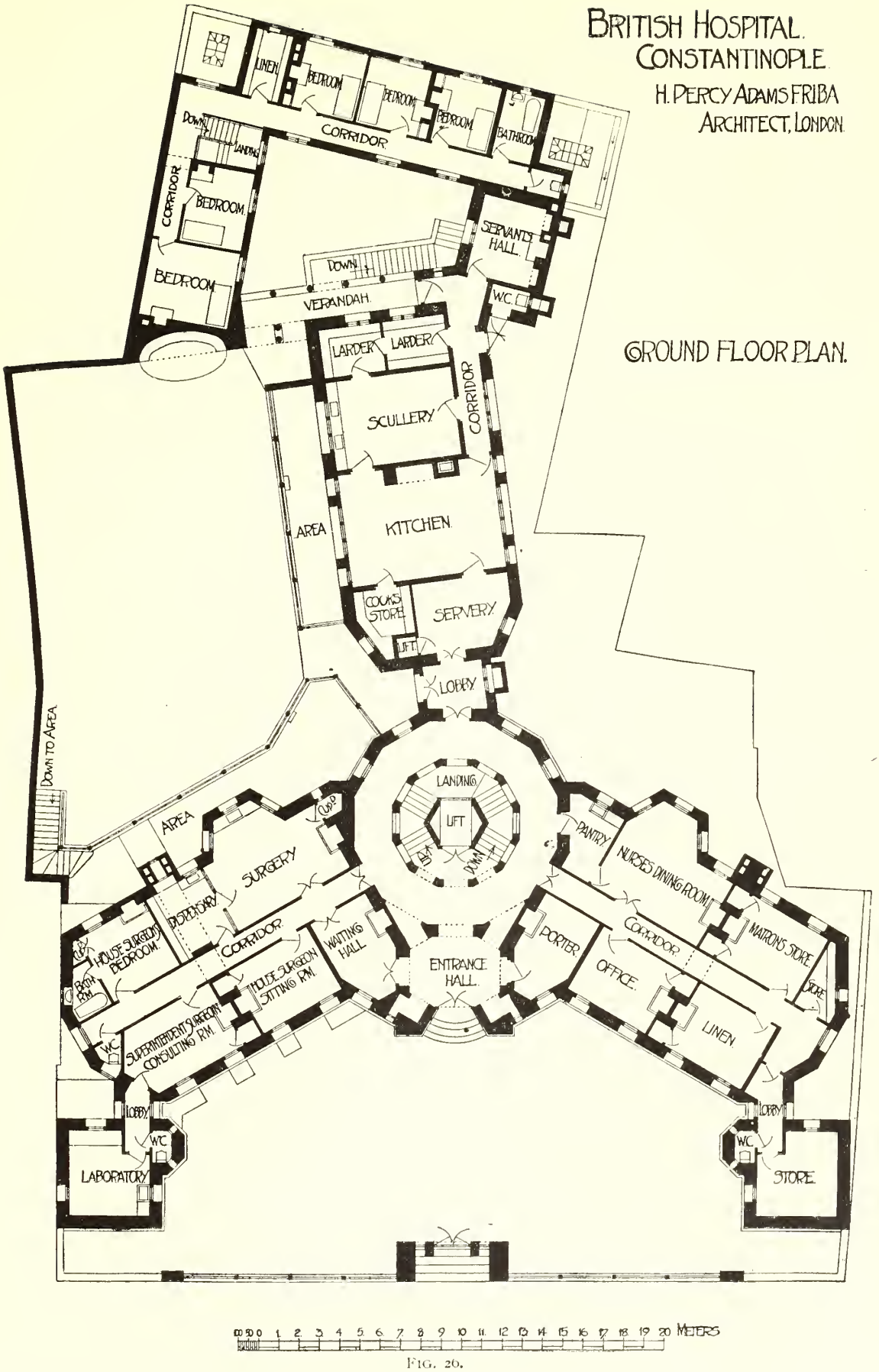

BRITISH HOSPITAL.
CONSTANTINOPLE.
H. PERCY ADAMS F.R.I.B.A.
ARCHITECT, LONDON.
GROUND FLOOR PLAN.
LINEN
BEDROOM
BEDROOM
BEDROOM
BEDROOM
CORRIDOR
BATHROOM
DOWN
LANDING
CORRIDOR
BEDROOM
BEDROOM
SERVANTS HALL
DOWN
VERANDAH
W.C.
LARDER
LARDER
CORRIDOR
SCULLERY
AREA
KITCHEN
COALS STORE
SERVERY
LIFT
LOBBY
DOWN TO AREA
LANDING
LIFT
LIFT
DOWN
AREA
CUPB
SURGERY
DISPENSARY
HOUSE SURGEONS BEDROOM
CORRIDOR
WAITING HALL
BATH RM
HOUSE SURGEONS SITTING RM.
ENTRANCE HALL
PORTER
PANTRY
NURSES DINING ROOM
CORRIDOR
MATRONS STORE
STORE
OFFICE
LINEN
SUPERINTENDENT SURGEONS CONSULTING RM.
W.C.
LOBBY
W.C.
LABORATORY
LOBBY
W.C.
STORE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 METERS

FIG. 26.

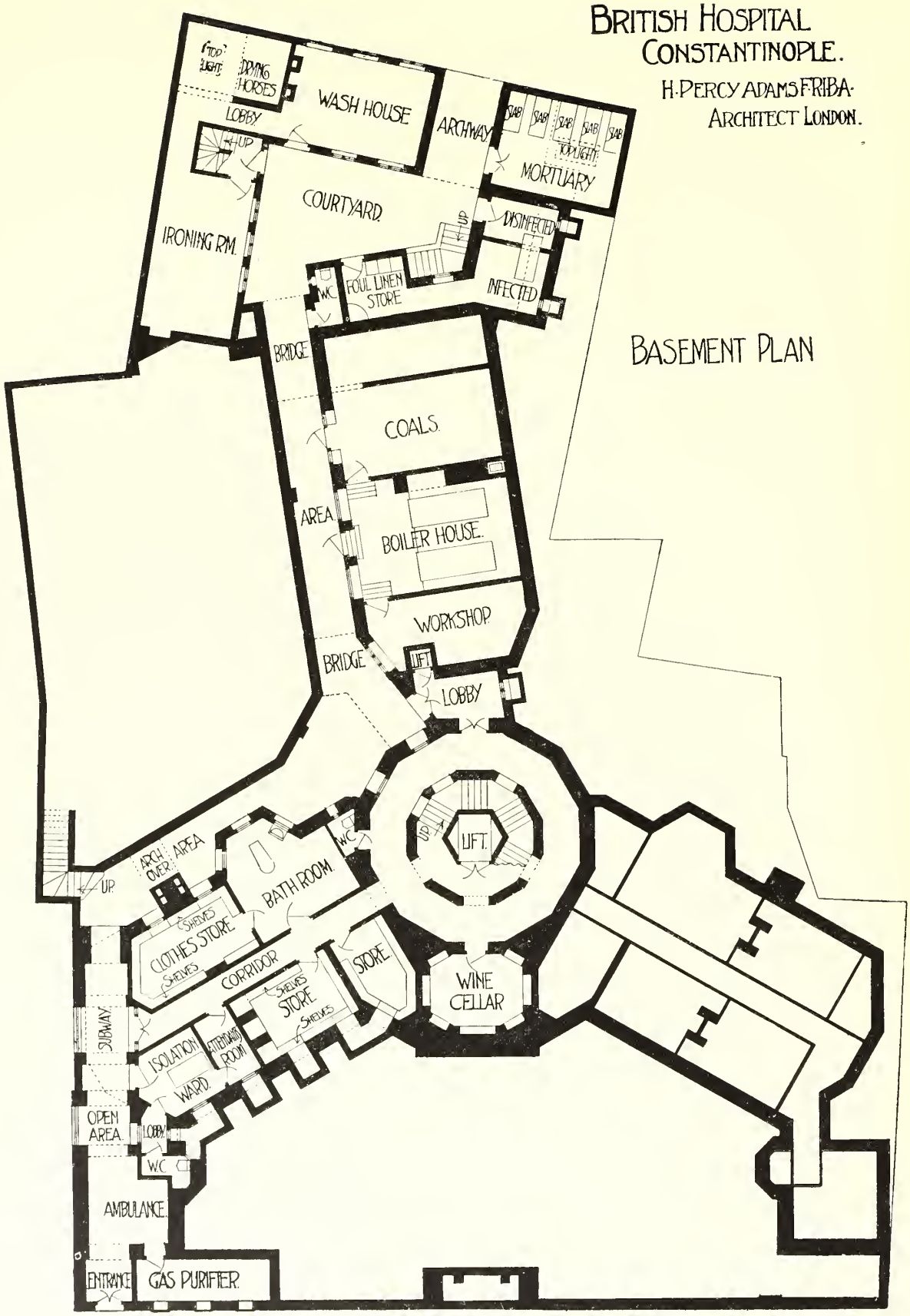

BRITISH HOSPITAL
CONSTANTINOPLE.
H. PERCY ADAMS F.R.I.B.A.
ARCHITECT LONDON.
BASEMENT PLAN
"TOP" LIGHT
DRYING HORSES
WASH HOUSE
ARCHWAY
SLAB
SLAB
SLAB
SLAB
SLAB
TOP LIGHT
MORTUARY
LOBBY
UP
COURTYARD
IRONING RM.
DISINFECTED
INFECTED
W.C.
FOUL LINEN STORE
BRIDGE
COALS
AREA
BOILER HOUSE.
WORKSHOP
BRIDGE
LIFT
LOBBY
UP
LIFT.
ARCH OVER
AREA
UP
W.C.
BATH ROOM.
SHELVES
CLOTHES STORE
SHELVES
CORRIDOR
SHELVES
STORE
SHELVES
STORE
WINE CELLAR
SUBWAY
ISOLATION WARD.
ATTENDANTS ROOM
OPEN AREA.
LOBBY
W.C.
AMBULANCE
ENTRANCE
GAS PURIFIER.

FIG. 27.

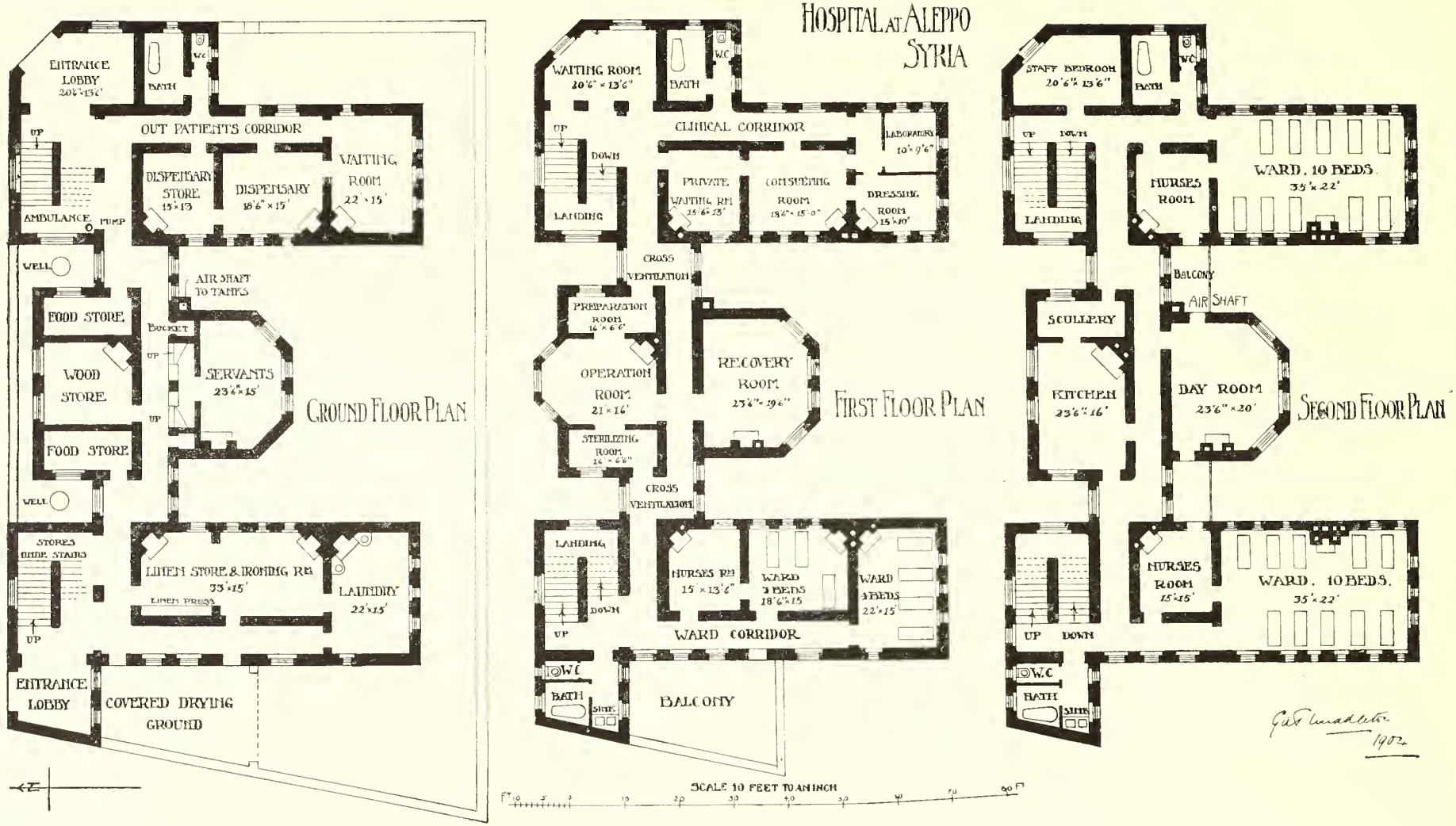

HOSPITAL AT ALEPPO
SYRIA
ENTRANCE LOBBY
BATH
W.C.
OUT PATIENTS CORRIDOR
DISPENSARY STORE
DISPENSARY
WAITING ROOM
AMBULANCE
PUMP
WELL
AIR SHAFT TO TANKS
FOOD STORE
WOOD STORE
FOOD STORE
BUCKET
SERVANTS
GROUND FLOOR PLAN
STORES
SIDE STAIRS
LINEN STORE & IRONING RM
LINEN PRESS
LAUNDRY
ENTRANCE LOBBY
COVERED DRYING GROUND
WAITING ROOM
CLINICAL CORRIDOR
LABORATORY
LANDING
PRIVATE WAITING RM
CONSULTING ROOM
DRESSING ROOM
CROSS VENTILATION
PREPARATION ROOM
OPERATION ROOM
RECOVERY ROOM
FIRST FLOOR PLAN
STERILIZING ROOM
NURSES RM
WARD 3 BEDS
WARD 4 BEDS
WARD CORRIDOR
BALCONY
SINK
STAFF BEDROOM
NURSES ROOM
WARD. 10 BEDS.
BALCONY
AIR SHAFT
SCULLERY
KITCHEN
DAY ROOM
SECOND FLOOR PLAN
SCALE 10 FEET TO AN INCH
1902

FIG. 28.

rooms and the matron's stores, that under another to the surgeon's department, and that under the third to the kitchens, while beyond the kitchen block there is a staircase leading down to an open area or courtyard; and round this, on the ground-floor level, are ranged a series of bedrooms for the kitchen staff. There is, perhaps, no need to explain these premises in detail, for to do so would be only to repeat what has been said before in other cases, but the planning is well worthy of a good deal of careful study, showing, as it does, how essential requirements can be met under difficult circumstances; for everything is provided here that is necessary for proper service as completely as at the Bedford County Hospital, yet under quite different conditions and in a different way. In fact, upon a restricted site there is a great deal always to be said for a radial arrangement such as is here resorted to.

The basement shown in Fig. 27 has a separate low-level entrance in the front, where an ambulance is placed. A series of open areas and subways lead round the building to the courtyard at the back, just recently mentioned. Out of this there is also an archway to a back street, and close to the archway is the mortuary and the disinfection apparatus, following, on a small scale, the lines of that at Tooting already illustrated. There is also here a washhouse and ironing-room, forming a complete laundry, all the linen being disinfected before it is taken to it. Under one of the front ward-blocks there is a small isolation ward and attendant's room, but the space is mostly given up to stores and a large bathroom.

This building is one of somewhat unusual beauty for a hospital, in spite of its extreme simplicity, as will be seen by a reference to Plate II., in which it is shown in a coloured perspective, outlined in pencil—a remarkably fine example of such work.

Another hospital, planned upon the usual lines but upon a restricted site and to meet somewhat special circumstances, was that designed for erection at Aleppo, in Syria. The aspect allowed the wards to run north and south in the generally accepted correct way, but as the prevailing wind was south-west, and it was important to give it full play, the annexes were not placed in the usual position. The plan, too, was largely controlled by the fact that the hospital had to serve also as a private doctor's consulting establishment, and, as it was entirely a private affair, it was also necessary that it should be capable of division at some future date into at least two private houses. Internal partitions, as we understand them, were almost impossible of attainment, as both internal and external walls would be thick and built of stone, all the floors being of stone arches between girders, and the roof being flat. The only water obtainable for drinking purposes was the rain-water caught on the roofs, and this had to be stored in a large tank in the basement, having windows of considerable size so as to admit the prevailing south-west wind to the tank. Water of a brackish character, for other purposes, such as washing, could be obtained by sinking deep wells through a rocky substratum. Two general wards containing ten beds each were required, but any other wards would be better if smaller, as they would probably be occupied by paying patients. With these conditions to meet, the plan shown in Fig. 28 was devised, and, like that of the last two hospitals considered, it was dominated by the requirements of the ward or second floor. This was of much the usual type, containing two ward-blocks and a central block also, in which the kitchen and dayroom were placed, the kitchen being somewhat exceptionally located on the upper floor, for the purpose of serving the wards easily. There were two main staircases on account of the stipulation for future division, but no lift, as such would have to be sent out from Europe together with the European workmen for its erection. The small spans of the rooms were also demanded by this consideration, as any steel work would have to be carried for a long distance up country. The air shaft shown was for ventilation of the rain-water tank, which was placed in the basement beneath the dayroom block, while the flat roof above was utilised as recreation ground. On the first floor one of the blocks was devoted to small wards, the central portion to a proper operation department, and the other block to consulting-rooms and surgeon's dressing-room for private patients, there being two waiting-rooms. One of these was for the use of the general lower class public, and the other for persons of a higher caste who would not mix with the common herd. It will be seen that the three blocks are on all floors perfectly disconnected by cross ventilation. On the ground floor there were two large entrances of sufficient width for carriages to drive or be backed right in, so that patients could be brought to the hospital in a carriage and the doors shut before they were taken out. Under the block of small wards was a laundry, while the central block was given up to stores and a servant's room, and the other to a dispensary for out-patients of the lower class, who had a small door by which they could obtain access or through which they might be dismissed.

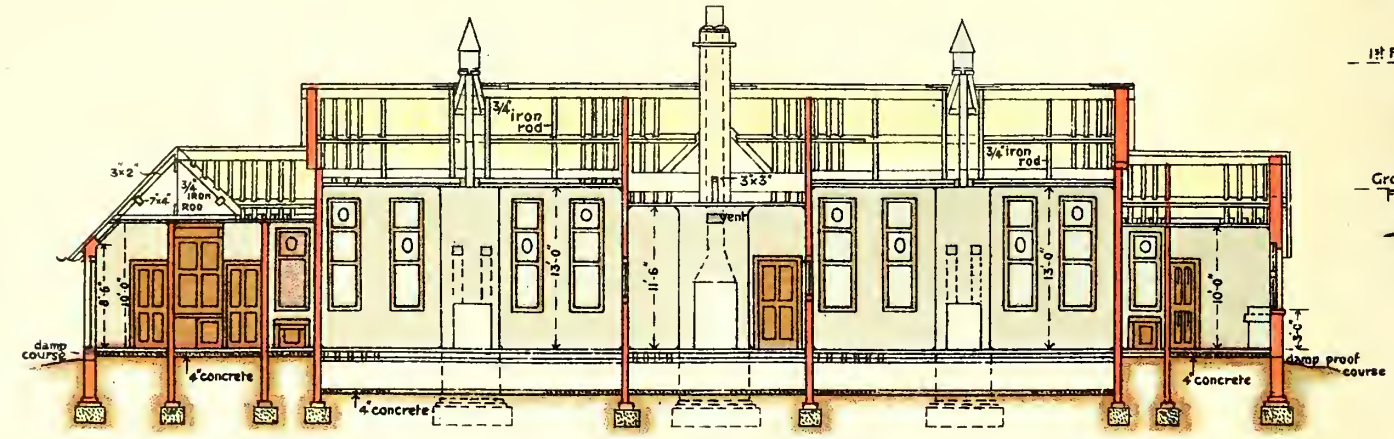
PLATE II

BRITISH HOSPITAL, CONSTANTINOPLE

H. PERCY ADAMS, F.R.I.B.A.

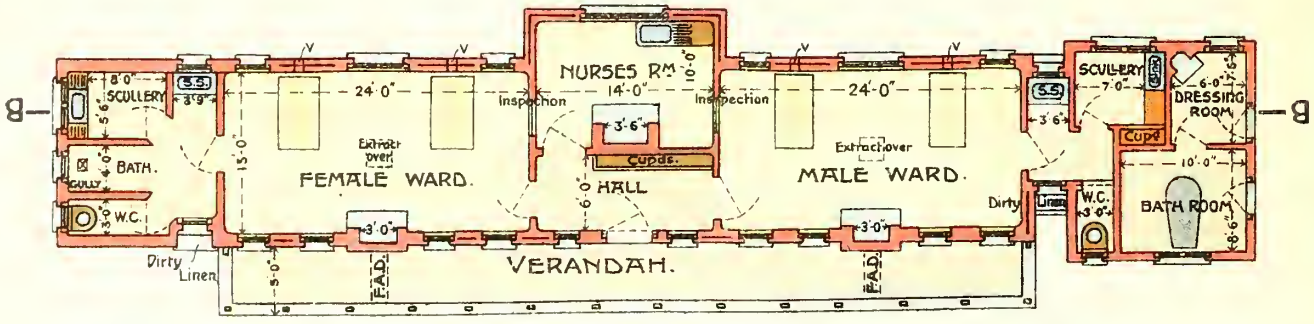
LINSLADE · RURAL DISTRICT COUNCIL
HOSPITAL FOR INFECTIOUS DISEASES.

THOS H·BISHOP. A·R·I·B·A · ARCHT LEIGHTON·BUZZARD.



Section B.B.

N.W. Elevation.

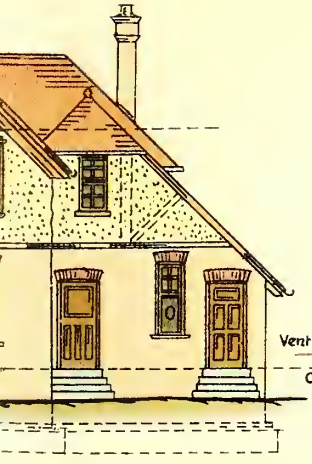


Plan. Diphtheria Block.

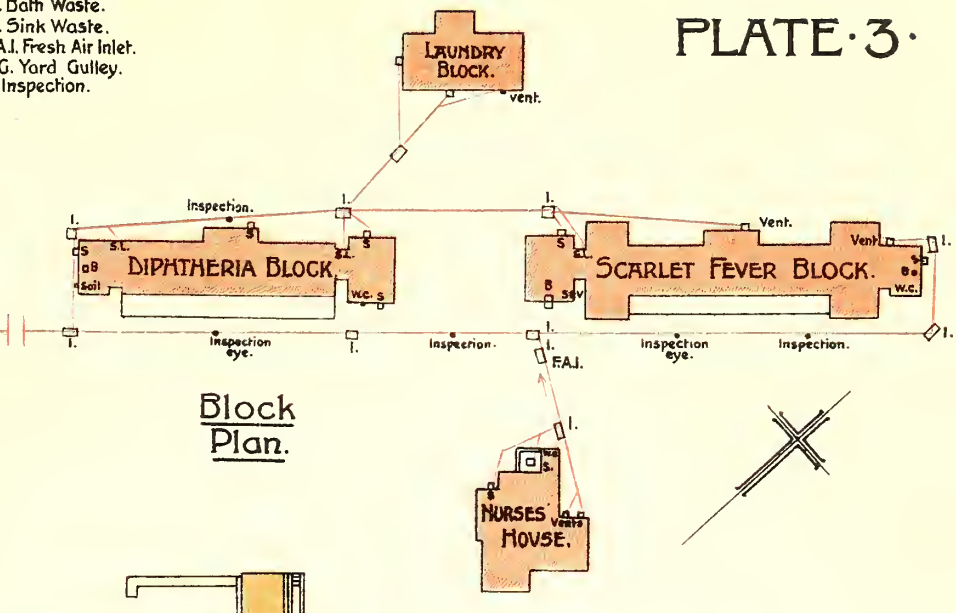
FT 10 5 0 10

PLATE·3·

REFERENCE.
S.I..Stop Sink Waste.
B. Bath Waste.
S. Sink Waste.
F.A.I. Fresh Air Inlet.
Y.G. Yard Gulley.
I. Inspection.

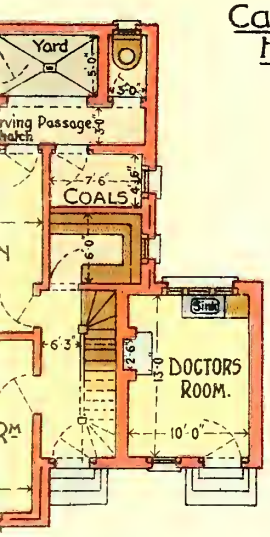


.Elevation.

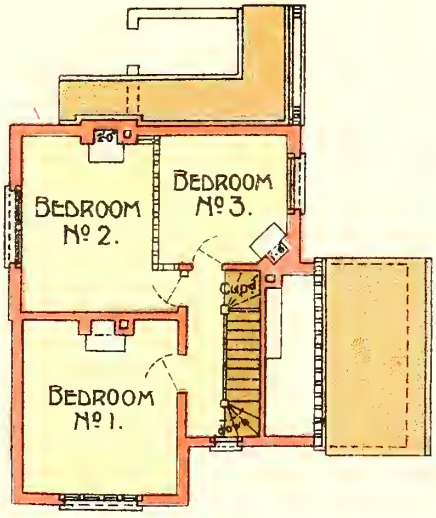


Block Plan.

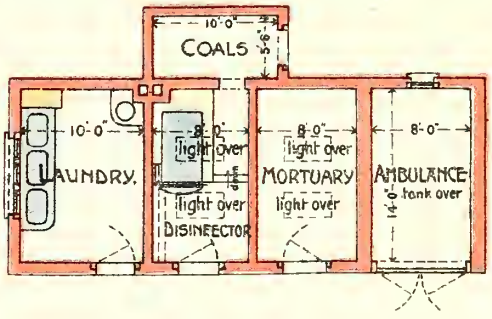
Caretakers House.



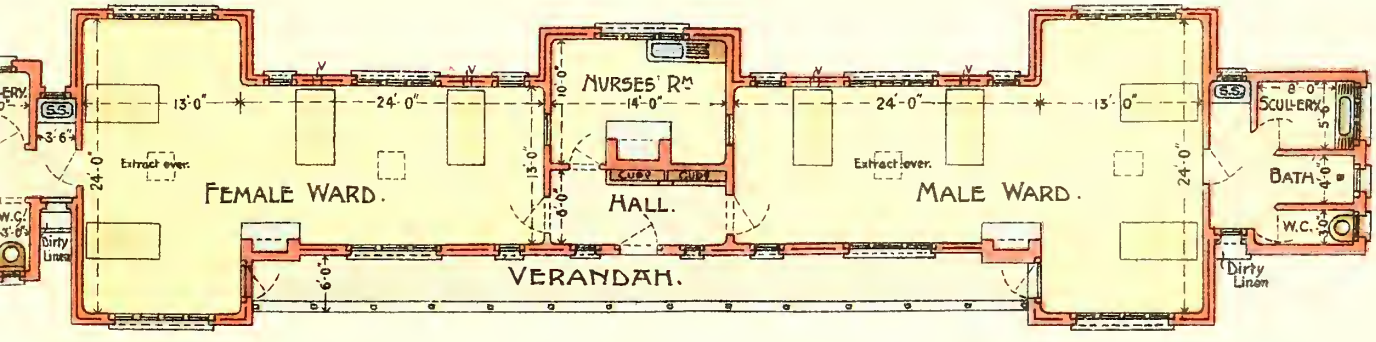
round Plan.



First Floor Plan.



Plan.
Laundry Block.



Plan. Scarlet Fever Block.

OF FEET.
20 30 40 50

CHAPTER VIII

SMALL AND SPECIAL HOSPITALS

Although in quite small hospitals the general principles of disconnection and the arrangement of the wards apply just as they do in large ones, yet in some cases there is greater opportunity, and in others there is less; and, in fact, a small hospital on a very open country site is naturally so well placed with regard to air space that considerable liberties may be taken with impunity. When dealing with infectious diseases, however, it is impossible to be too cautious, and it is now generally held that more successful treatment results in small than in big hospitals, if the utmost advantage is taken of the opportunity to allow fresh air to play round every individual block, and to keep the wards as small as possible.

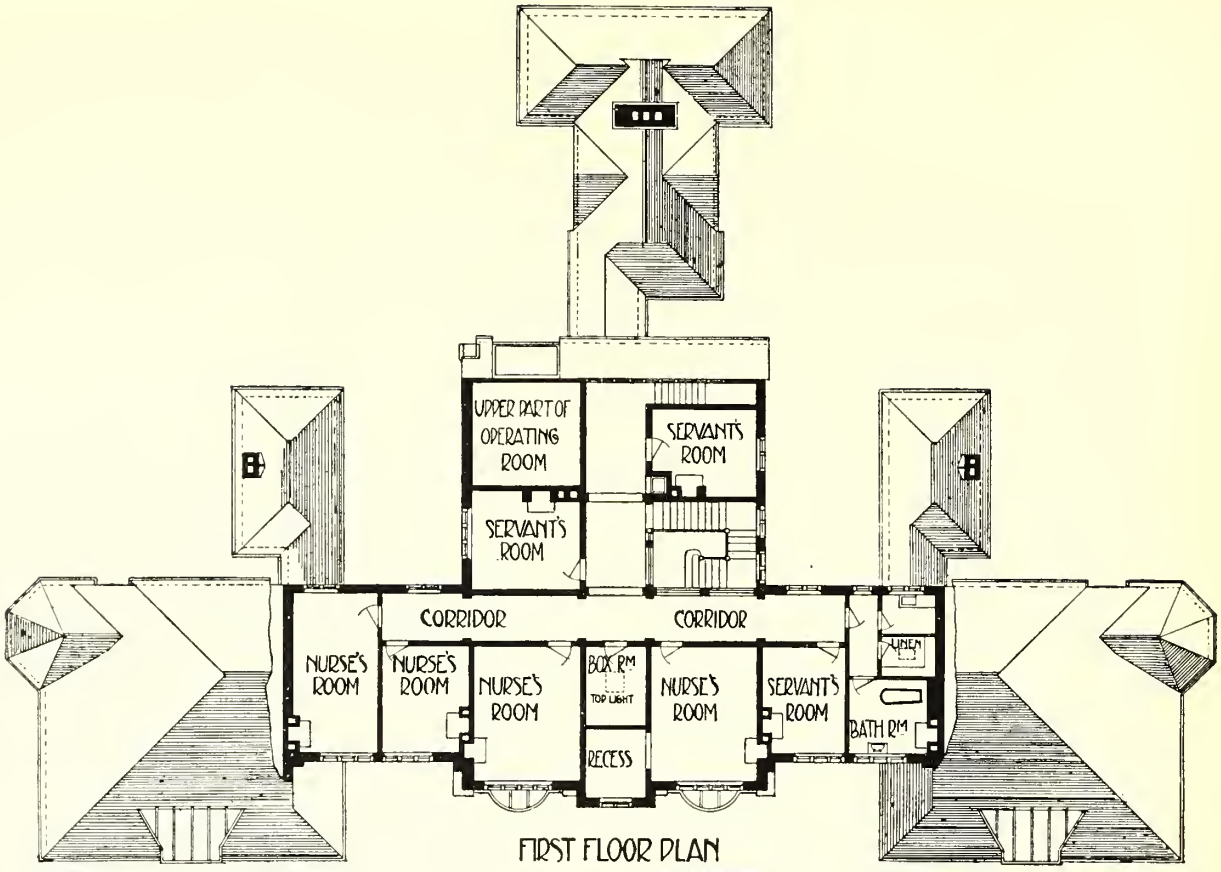
An example of this is illustrated in Plate III., which shows a little fever hospital erected at Linslade, near Leighton Buzzard, from the designs of Mr. T. H. Bishop, A.R.I.B.A. The general arrangement can be observed upon the block plan, from which it will be seen that there are four small detached houses or blocks with no communication between them other than gravel paths and electric-bell wires, everything having to be carried, between the blocks, absolutely through the open air in all weathers, not even covered ways being provided. There is a nurses' house in the front, replacing the administrative block of a larger hospital; then behind that, to the north-west, are two infectious diseases blocks, one reserved for diphtheria cases and the other for scarlet fever, and beyond these again, reached by a path which passes directly through from back to front, there is a small laundry and mortuary block.

The nurses' house is planned in rather a special manner. There is a doctor's room in the front, with windows both at back and front so as to secure through ventilation, and this room is separately entered, so that the doctor need not come into contact with the servants. The kitchen is so arranged that the food intended for the patients is carried out through a back door to an open covered passage, and passed from there into a small covered servery, whence it is fetched by the ward nurses, who, during duty hours, do not enter the house, although they live in it when off duty.

There is always one nurse on duty in each ward block, and for her use there is provided a dressing-room and bathroom at the end of the block, to enable her to change her clothes both on entering and leaving. She enters through the dressing-room entrance, then passes into the bathroom and assumes her nurse's clothes, passing out through the external door of the bathroom to her duty; and the process is reversed when she comes out, except that on that occasion she takes a medicated bath as a matter of course before assuming her ordinary clothes. There is no direct communication between these rooms and the ward, and she thus has to traverse a short distance in the open air on each occasion.

The two blocks are very similarly planned, upon the principles already laid down, except that, as the hospital is small, the wards are narrow and contain only one row of beds, while there is a verandah right along the whole of the south-east front. The roof to this is broken through wherever windows occur, to enable these to be carried up to ceiling level without obstruction to either light or air, and the entrance hall is lighted by a window above the verandah roof, as well as by two windows beneath it on either side of the doorway. All linen after use is thrown out through one of the windows of the disconnection passage between the ward and the sanitary block into a dirty-linen basket, and is taken thence to the disinfector, while the clean linen is brought back to the central hall and stored in the cupboards until needed, just outside the nurse's room. This is placed centrally in each of the blocks, with inspection windows opening into the wards, of which that for scarlet fever patients is made with short transepts in order to economise by reducing the spans, and the opportunity is taken of placing doors there which open directly upon the verandah. An objection to this form of ward might well be raised, in larger hospitals, that there were corners which were not under observation by the nurses, but the space so hidden from the nurse's room is insignificant in a small ward, and the beds at least are always visible. The bathroom in connection with the ward can hardly be properly called a room, as it is only 4 feet wide. It is, in fact, nothing more than a recess into which a bath can be wheeled for filling and discharge, and in which it is stored, as in every case it would be taken into the ward for actual use.

As in the whole hospital there are only twelve beds, the laundry block is naturally quite a small thing. There is one room for the steam disinfector, so that the clothes can be passed through it from end to end, and thence to the laundry, which also consists of a



FIRST FLOOR PLAN

COTTAGE HOSPITAL AT WOBURN FOR THE DUKE OF BEDFORD

H. PERCY ADAMS F.R.I.B.A. ARCHITECT

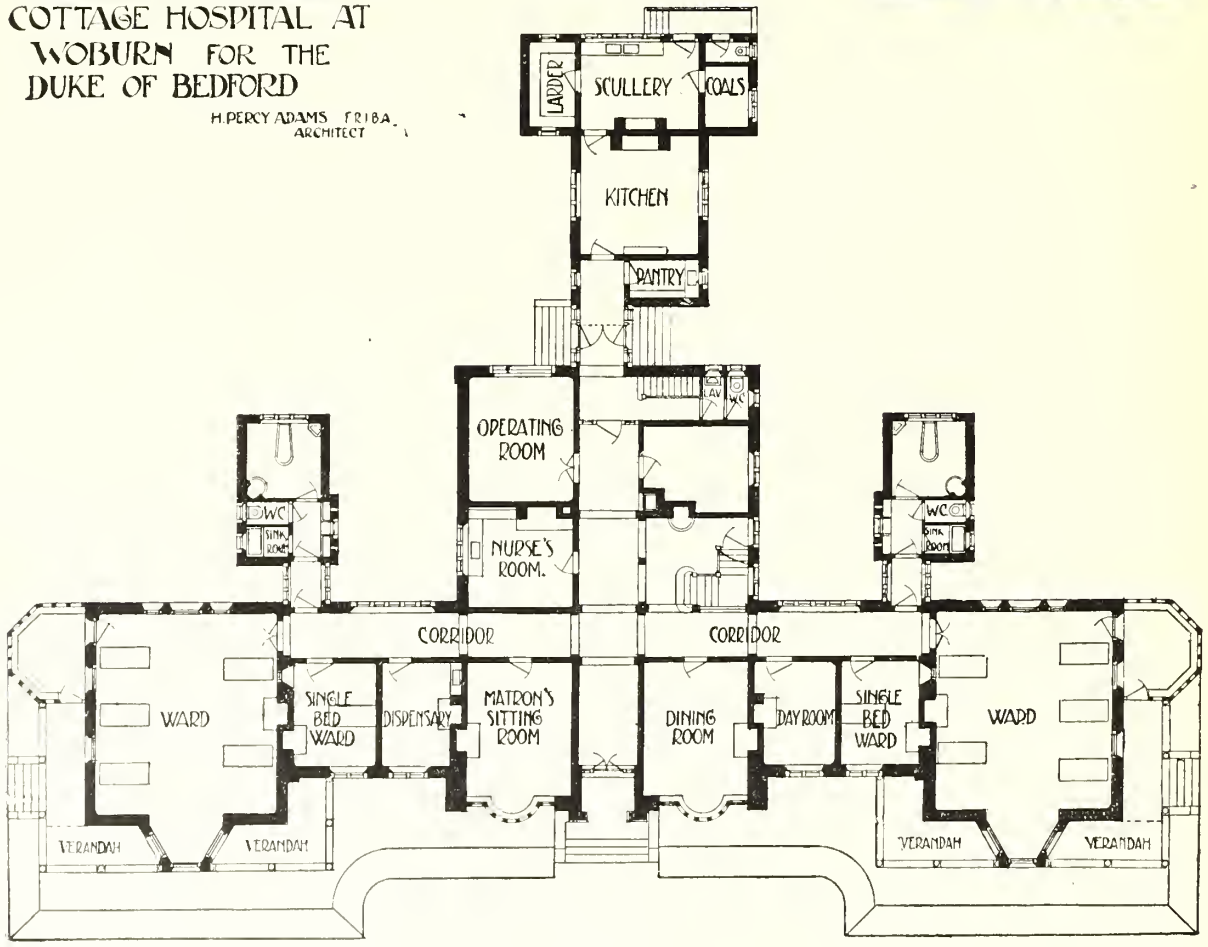
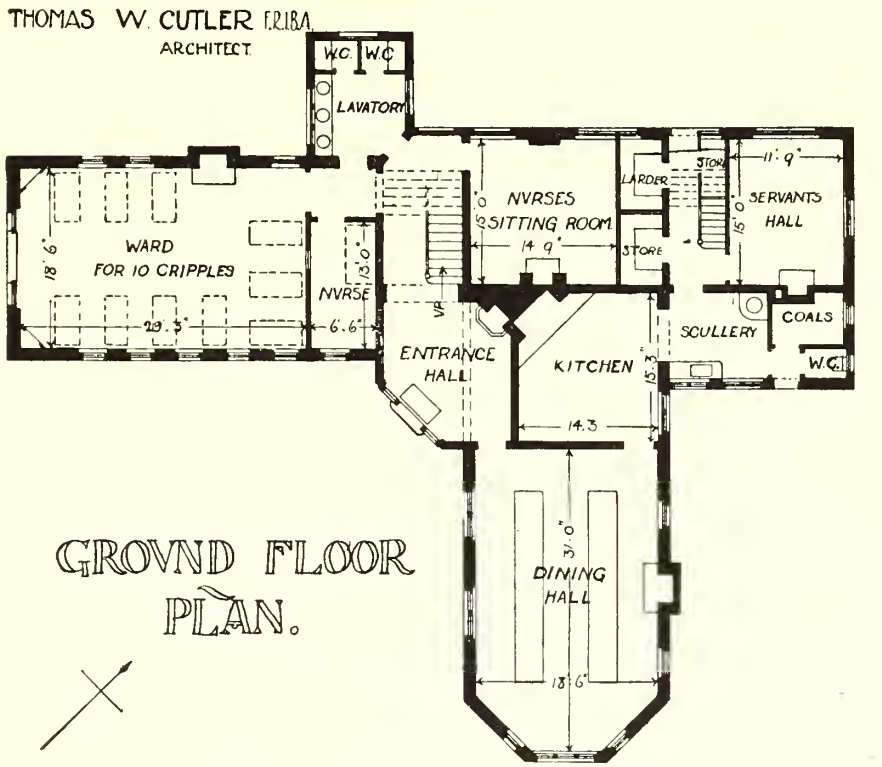


FIG. 29.

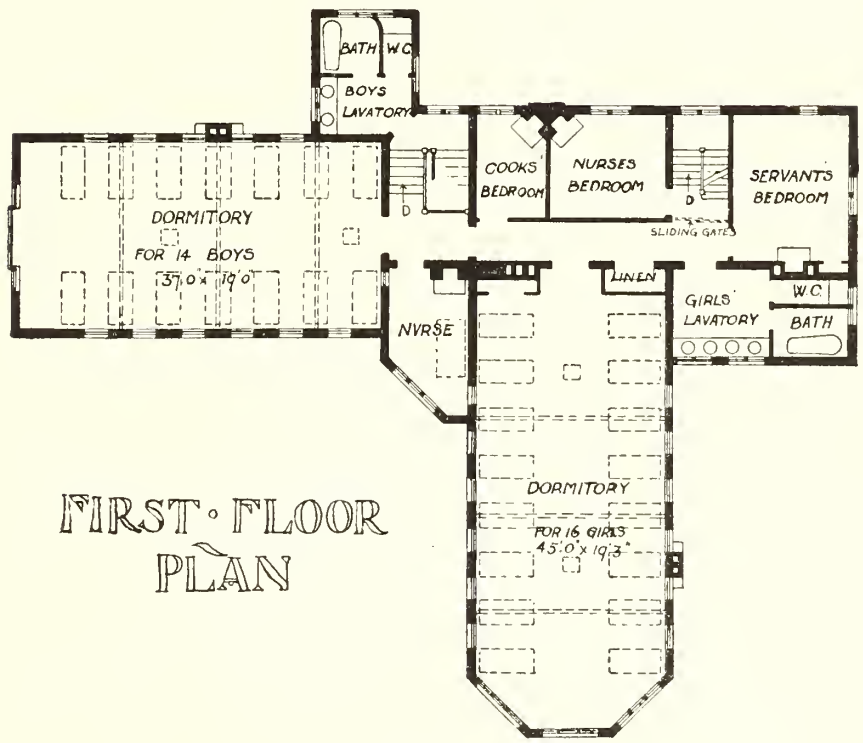
CONVALESCENT HOME HIGH BEECH.

SCALE OF FEET 5 0 10 20 30 40

THOMAS W. CUTLER F.R.I.B.A. ARCHITECT.



GROVND FLOOR PLAN.



FIRST FLOOR PLAN

FIG. 30.

single room only. The mortuary, too, is quite a small room, and necessarily well ventilated, while an ambulance-room is also provided, just large enough to take a small vehicle for the conveyance of patients. This has somewhat thick walls, as the water tank which supplies the whole of the place is built over it.

The cottage hospital at Woburn, designed by Mr. H. P. Adams, F.R.I.B.A., for the Duke of Bedford (see Fig. 29) is a very perfect example of a small hospital for a country place, intended for other than infectious cases. There is not such perfect disconnection, perhaps, as in the Linslade hospital, nor is it necessary under these circumstances, but everything is about as perfect as it well could be in accordance with modern accepted ideas. There is, on a small scale, the same departmenting that would be found in a large hospital. The central block in the front is devoted to a matron's room and a staff dining-room, and at the back to a nurse's room and an operating-room, the latter being carried up two storeys and partially top lighted, with its window on the north side. To right and left of this block a transverse corridor passes direct to the wards, this corridor having a large window at one side forming quite sufficient disconnection when the cases are of an ordinary type, the side opposite the window being taken up by a dispensary, a dayroom, and two single-bed wards. The main wards contain five beds each, one being intended for men and the other for women, and they are so planned as to be pleasing in appearance, with large bay windows on the south side and a conservatory opening out of each, opposite the entrance from the corridor, while they are almost surrounded by verandahs. There is a small inspection window between the single-bed ward and the main ward, so that the nurse in charge could inspect both, whichever room she might happen to be in. The sanitary blocks, it will be seen, open out of the corridor and not out of the ward, and are properly disconnected. By this arrangement they never cut off any direct sunlight at any time of the day, for they are on the north side.

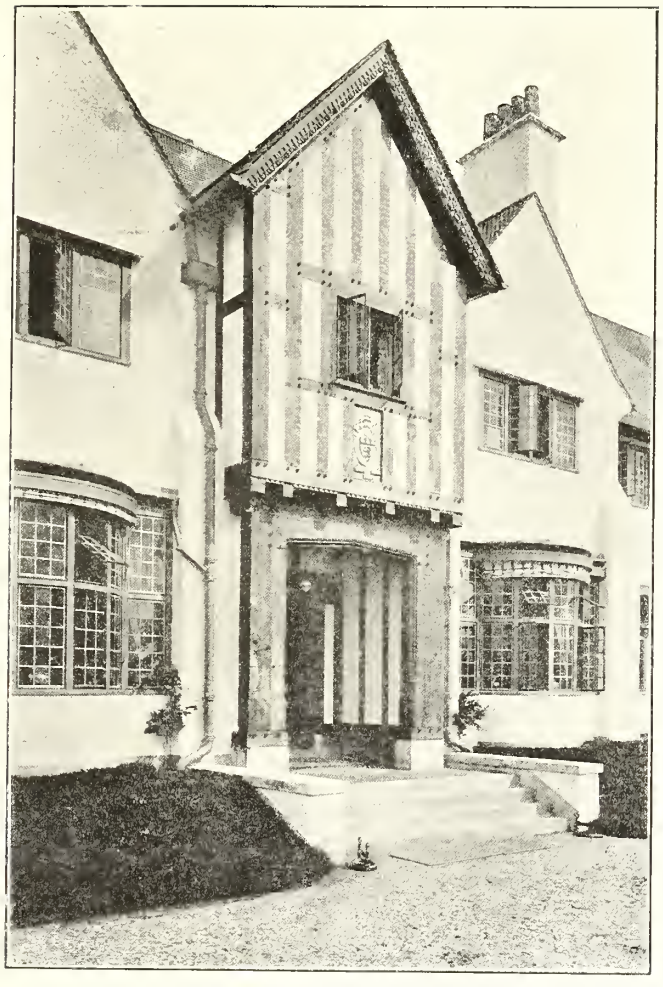
It may be noticed in passing that lines have been drawn across all the openings showing the position of the walls and arches above them. This is often done in order to save time in an office, but it is hardly to be commended upon working drawings, as such lines might possibly be confounded with those usually employed to denote steps, for which they must not here be mistaken.

The main entrance, which is in the centre of the block, leads into a central corridor, and this passes straight through to the kitchen department in the extreme rear, cut off from the main administrative department by proper disconnection doors. The kitchens are in this case not much larger than those of a good sized country house and no more complicated, there being only one larder and one pantry, this latter being kept on the hospital side of the kitchen, so that no possibly infected plates or dishes are passed into the kitchen until they have been washed.

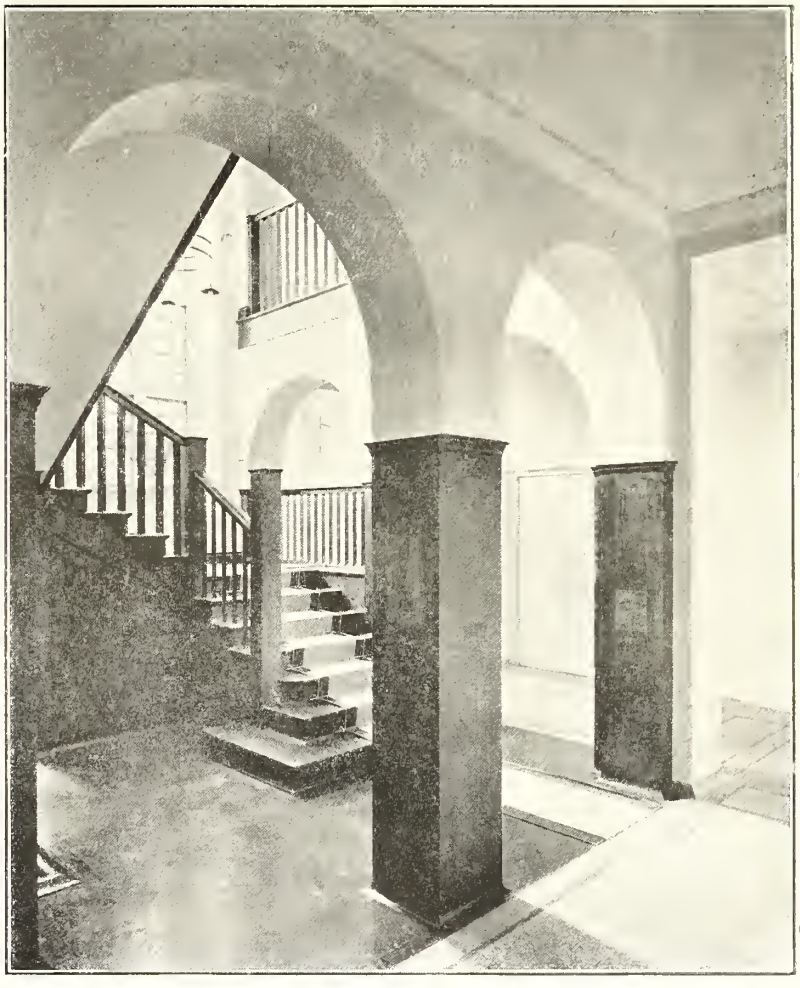
The whole of the central portion of the building is carried up two storeys in height, the upper floor being devoted to a series of bedrooms for the use of nurses and servants, who are unusually well provided for. As will be seen from the photographs illustrated in Plate IV., a great deal of care has been taken to make this a pleasant and homely building. When the necessary expense can be afforded there is undoubtedly a good deal of advantage to be gained by placing sick persons amidst pleasant surroundings. It has even been found possible to make the interior pleasing as well as the exterior, though all the ordinary hospital requirements are observed. The ordinary projecting architrave to doors and windows, for instance, not being permissible, they have been replaced by coloured bands worked in tiles. Colour has been used in this way to a considerable extent, yet entirely without fussiness, broad surfaces of pleasant tone relieved by carefully placed lines being all that is depended upon for effect.

A Convalescent Home, such as that erected at High Beech, and shown in Figs. 30 and 31, of which Mr. T. W. Cutler, F.R.I.B.A., is the architect, is in all essentials a small hospital, except that there is no necessity for a specially arranged administrative department, nor for surgeon's and operating-rooms. It is, however, necessary to provide a large dining-hall, as convalescents, unlike hospital patients, do not remain always in their wards, and while perfect disconnection is not essential, yet fresh air and sunlight are very much needed. Instead of extending in one long line, the wards are here placed at right angles to one another, forming an L-shaped plan. On the ground floor, the dining-hall occupies the space usually allocated to a ward, and immediately behind it is the kitchen, from which it is directly served. The entrance-hall is placed at the re-entering angle, the dining-hall opening directly out of it on the right, while a staircase rises from it also, and beneath the staircase a series of lavatories are reached, with a semi-disconnected block on the left containing a ward for ten crippled children, with a nurse's overlooking-room. There is also a nurse's sitting-room on this floor.

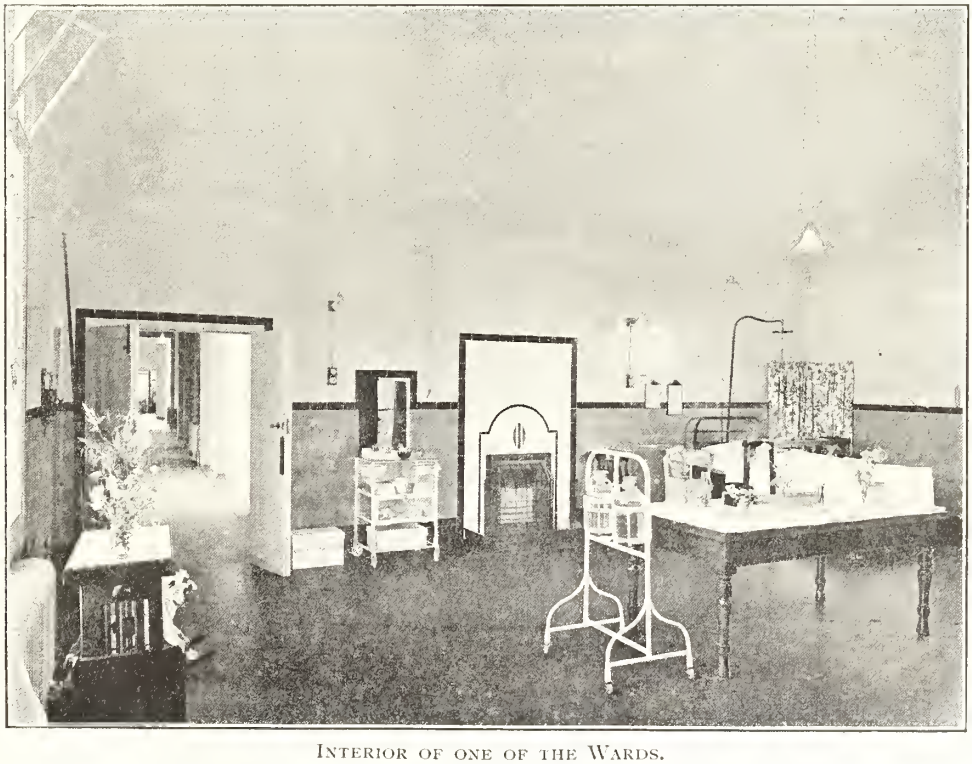
The servants' quarters are entirely distinct from those of the nurses, communication only being possible through the kitchen and dining-hall, except on the first floor, to which the servants have separate access. There are thus two staircases, providing a secondary means of escape in case of fire. The upper floor follows the ground floor very closely, but the bedroom accommodation for the staff is somewhat small, or would be so if it were not possible for nurses to sleep in the duty-rooms, there being no necessity in a convalescent home for a nurse to be always awake.



FRONT ENTRANCE.



ENTRANCE HALL.



INTERIOR OF ONE OF THE WARDS.

HOSPITAL AT WOBURN FOR THE DUKE OF BEDFORD.

H. PERCY ADAMS, F.R.I.B.A.

The large dormitories are on the upper floor, and a single duty-room serves for both. Where neither space nor money is restricted there is a good deal to be said in favour of this L-shaped plan, especially when arranged, as in this case, with regard to the points of the compass, the patients obtaining full advantage of the sunshine, while the kitchens are upon the cool side.

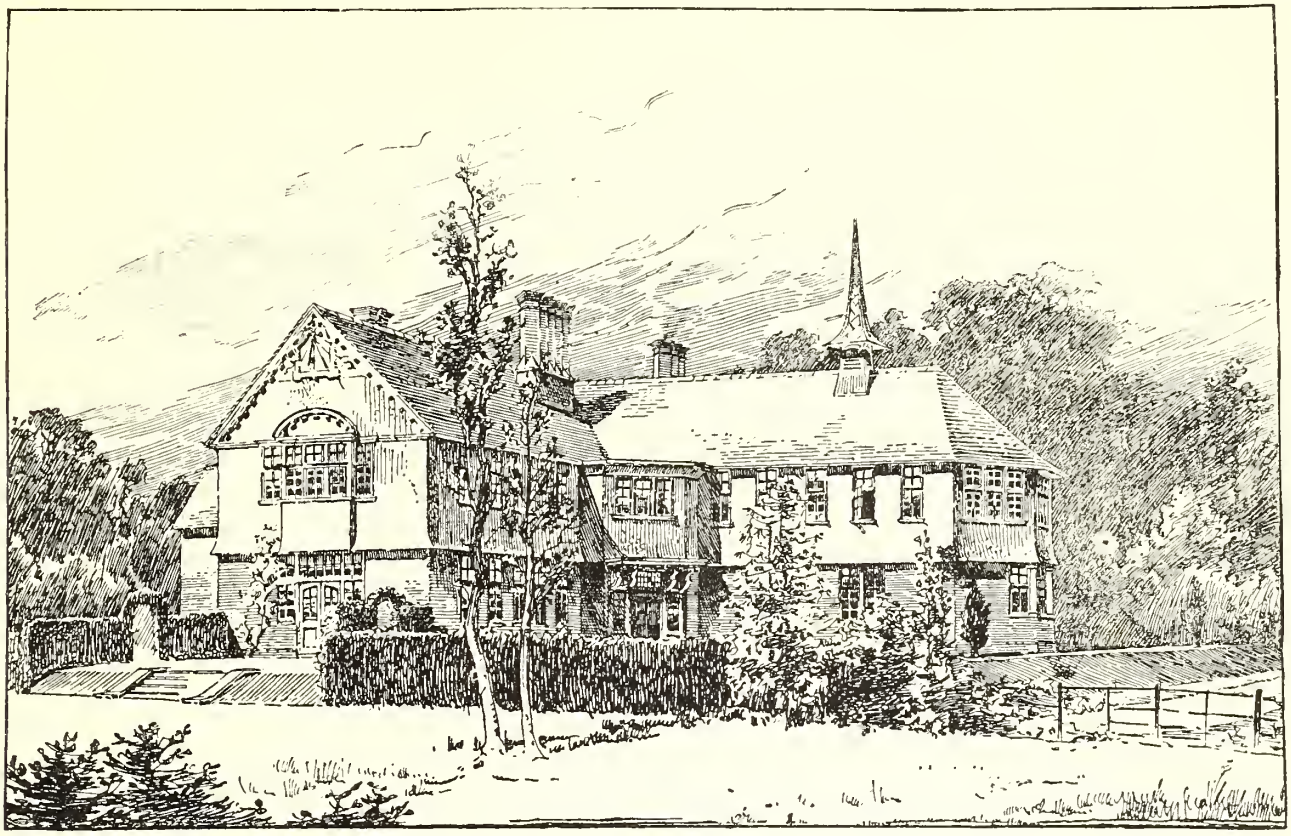


Fig. 31.—Convalescent Home at High Beech. By T. W. Cutler, F.R.I.B.A.

PART II

THE LAW OF EASEMENTS

(Contributed by J. Bridges-Lee, M.A., Barrister-at-Law)

CHAPTER 1

THE PRINCIPLES OF EASEMENTS—LIGHT AND AIR

Most buildings would be either useless or of very little value if they could not be adequately lighted and ventilated. Dwelling-houses, offices, and workshops specially require plenty of daylight and fresh air in nearly every part of the interior, in order that they may be cheerful, healthy, and efficient places to live or work in. Therefore anyone who is concerned in designing modern buildings must of necessity give considerable thought and attention to some of the practical problems which may arise when a scheme for lighting or ventilating new premises has to be decided upon.

Often there are collateral circumstances which interfere with the execution of an ideal scheme, and must be taken into account. For example, there may be persons owning neighbouring land or buildings who might have a right to interrupt the free passage of light and air across their property, or perhaps the same or some other neighbours, by virtue of their proprietary rights, may enjoy some easements over the land whereon it is proposed to build, so as to have a right to object to the new buildings, wholly or in part, as an interruption of the enjoyment of their easement.

In such cases it may be necessary to depart more or less widely from an ideal scheme, unless it is found possible to arrive at some agreement with the neighbours concerning those matters about which there appears to be a conflict of rights and interests.

Also, it may be necessary or expedient in many cases to take account of probable or possible future developments or dealings with the property, or separate parts of it.

For example, suppose it is intended to develop a large estate where the proprietary rights of the whole are vested in the same person or group of persons acting as one. In such cases there would be no immediate conflict of interest between the owners of neighbouring plots within the estate (the owner being the same); but it would be certainly imprudent for that reason to neglect to take into account the way in which each plot, and the building upon it, or to be afterwards erected, would be affected by the buildings on neighbouring plots. Evidently the ultimate value of the whole property will depend upon the sum of the value of the separate parts, and when the property begins to be broken up by the sale of separate plots or buildings conflicts of interest may immediately arise between the vendors and the vendees of the detached parts, and also between the several vendees.

The means by which conflicts of interest relating to the access and ingress of light and air to buildings may arise between neighbours are really very numerous, and often by no means easy to adjust. In towns, especially in congested neighbourhoods, when anybody wishes to build (whether by way of adding to old buildings or by pulling them down and erecting new ones), the complexity of the problem to be solved may be such that there may be practically no way out of the difficulty short of buying up, if possible, several or all of the surrounding land and buildings, or abandonment of the project.

Much will always depend upon how far neighbouring proprietors are disposed to stand upon their real or supposed rights to light and air, or their disposition and power to legally obstruct the light and air which might be desired or necessary for the proposed new buildings.

No one owning old buildings with what are commonly called "ancient lights" can afford to ignore building operations of his neighbours which seriously affect his lights, or he may lose his rights partially or altogether

after an interruption of a year, and his property may then suffer a very heavy fall in value. On the other hand, the possession of "ancient lights" may confer a greatly enhanced value upon any kind of building. Also a careful and watchful preservation of the easement will often confer a considerably increased value upon the site, because if the particular building is pulled down to make way for a better one the easement may be preserved, and new windows in the same positions may be opened in any new building erected on the site without infringing the rights of neighbours.

The same reasons which make it advisable for a proprietor to jealously guard any special rights of light and air which he may enjoy as easements appertaining to his property will induce prudent proprietors generally to be watchful and on guard lest new easements may be acquired for neighbouring properties which may impose new burthens on theirs.

Speaking generally, the acquisition of an easement of light for one tenement is more or less decidedly inimical to the interests of neighbouring properties, so that owners of houses and building sites are scarcely, if at all, less interested in protecting their property from the gradual accrual of new easements, which may impose additional restrictive burdens upon their property, than are the owners of dominant tenements in sustaining the rights of easement already appertaining to their property.

Sometimes the ownership of very insignificant buildings possessing ancient lights will afford opportunities to the owners to put forward most extortionate demands for compensation for obstruction of the lights, or for the purchase of the houses, and great and useful schemes for the improvement of old neighbourhoods may be seriously retarded or financially crippled by the extortionate demands made. Courts of Equity will not regard with favour any attempts at extortion by this or other means, but law suits may be costly and last long, and doubt or delay may be very injurious to the people concerned with building, so that in a large proportion of cases extortionate demands are paid right and left to clear away opposition and facilitate rapid progress.

So far as possible people concerned with building schemes should make arrangements in good time to secure freedom from opposition or extortion when work is in progress.

The builder, or those persons who are directing building operations, should especially take care so to arrange matters in advance, if possible, as not to be liable to be blackmailed by people who, by standing upon their real or alleged rights, might be able seriously to obstruct progress, and to demand a big price for ceasing to be obnoxious and obstructive.

On the other hand, while a builder should be careful to counteract the designs of blackmailing property owners, who would take the utmost advantage of his necessities to extort money if opportunity offered, he must also be careful to respect the honest claims of those who have rights which they use and enjoy. He should not so act as to confer fictitious fanciful values on property intrinsically of little value; while he must not, on the other hand, invade the rights of people whose property might be seriously injured in value by obstruction of lights really useful to them for health, comfort, or business purposes.

A builder or architect is not generally so much concerned about other people's air as he may be about their lights.

He should look after the efficient ventilation of his own buildings. He should see that the inlets and outlets for his ventilation are in convenient places where they are not liable to be easily obstructed, or the incoming air to be easily contaminated with objectionable matter.

Concerning the neighbours, he is not in an ordinary way very likely to block their ventilating inlets or outlets, especially if these are in or near the walls of the neighbouring houses, and on the neighbours' own lands. Air, unlike light, can travel round corners, and by all kinds of routes towards a hole in the wall; and nothing short of building quite close up to a wall will ordinarily stop access of air in such fashion as to afford a good ground of action.

It is to be understood that a natural right to sufficient air does not include a right to a breeze in any particular direction towards the building, so as to prevent a neighbour from obstructing breezes by building on his land.

Cases like the Nottingham cellar ventilation case, referred to in Chapter V., where the ventilating outlet is on a neighbour's land, are not common. All necessary provisions for ventilation are ordinarily made upon or in immediate association with the premises to be ventilated, so that without trespassing it is nearly impossible for a neighbour to stop access of air.

Concerning pollution of air, as a general rule a man cannot pollute air to the injury of his neighbours and their property without also injuring himself and his property to a like or generally to a greater extent; and when buildings for habitation are in question everybody is interested in having the air as sweet and pure as circumstances permit, and owners or occupiers are not likely to attempt to set up or to acquire easements to make offensive smells, or otherwise to poison or pollute the air. Sanitary inspectors or neighbours would soon take effective steps to stop nuisances of this kind if any attempt were made to perpetuate them by frequent repetition.

In practice the only people likely to be permitted to pollute air in a wholesale way, and as a regular habit, are public bodies of various kinds, and factory owners carrying on trades and manufactures which from their very nature must be more or less offensive to neighbours. Such trades and manufactures as are dangerous to life and health are generally subject to official inspection and regulation, and the proprietors may be

compelled to carry on their operations in ways which are least objectionable, so that altogether there is a tendency in modern days towards increased purity of atmosphere nearly everywhere rather than the reverse. There are still places where large quantities of more or less acrid fumes and smoke and smells escape into the atmosphere, and many of the places from which the nuisances originate have acquired easement rights by long uninterrupted use and enjoyment; but pressure of various kinds can be and often is brought to bear upon the owners and occupiers of buildings where these obnoxious and dangerous trades are carried on to confine their rights of pollution to the narrowest limits consistent with the successful carrying on of those trades.

Support

Rights of support for buildings are in some ways much more obscure, uncertain, and intricate when they come to be dealt with in practice than the natural rights or easements affecting light or air. Support is a statical resistance to displacement under the influence of gravity. It is not a form of motion appreciable by a special sense like light, nor a gaseous substance which spreads in all directions like air, but a steady resistance to change of position.

Most buildings depend for their support upon the ground below and immediately around their base. It is part of the ordinary business of a builder, under the direction of his architect, to take care that the buildings to be erected by him shall rest on sound foundations, which are laid with reference to the estimated qualities of the earth and rocks beneath the surface. If the foundations are not sound or adequate for the support of the building, and damage results, the blame must naturally fall on those persons who are responsible for the bad design or construction.

When valuable buildings are to be erected, efforts are generally made to render the foundations so secure as to leave a large margin of safety for their support. At the best it is often impossible to say with any exactitude what the margin of safety actually is to begin with, or how that margin may be affected by natural or accidental causes as time goes on. Anything which tends to diminish the margin of safety will, *pro tanto*, jeopardise the safety of the building, and therefore deserves the attention of the owner, architect, and builder.

It is essentially their business to look after the safety of the building, and to provide adequate support for it on the land of the owner, and they should not look to neighbours to provide any part of the support for the building unless some definite special business arrangement is made in this connection. Ordinarily a neighbour has no sort of responsibility or duty in connection with the upholding of his neighbour's newly built house, and as the law now stands he will not incur any responsibility until the house has stood for twenty years, except under such special considerations as are explained in Chapter VI.

Complications are apt to arise when people mine or burrow under the foundations, or excavate friable earth from pits or hollows not very far away from the foundations.

In such cases the margin of safety for the support of the building may be taken away, and more or less serious injury may result. Such cases may present very difficult and delicate problems to deal with, because if the person mining, burrowing, or excavating has *primâ facie* a right to do these things he cannot be held to have exceeded his right until he had actually caused a failure of support, and not always even then, so that the householder may be in the awkward and unpleasant position of knowing that the earth support for his foundations is being weakened, possibly to a dangerous extent for the security of the house in which he lives, and yet not be able to take any really effective steps to avoid the risk.

The ordinary procedure by petition for injunction which is applicable to light and other cases where injury is threatened cannot be evoked in the majority of such cases, because of the generally obscure character of the facts to be dealt with. A man cannot be restrained by injunction from what he is entitled to do as a matter of right because it is possible that he may at some time go beyond his right; and *primâ facie*, if he has a right to excavate at all, he has a right to go on digging up to the actual point where support for the neighbouring building begins to fail, when he may become liable for damages if the owner of the building has an easement right binding upon his tenement and therefore also upon him. Some of the intricacies and peculiarities of the law relating to support are explained in Chapter VI. The most important practical lessons to be learnt from a study of the law relating to support would seem to be—(1) That every one who wishes to build a heavy or valuable house should ascertain as fully as possible the state of the subjacent earth as regards its solidity of substance and freedom from cavities at any depth. (2) He should be satisfied that sound foundations can be laid, and that nobody else has a right to burrow or dig in the immediate neighbourhood of his foundation, or at such a distance (if the earth is unsound) that support may be withdrawn from the neighbourhood of his foundations by draining or excavation. (3) If the conditions just referred to are unfavourable, some means of protection and safety may be provided by arrangements with the owners of neighbouring tenements.

In some coal-mining districts large tracts of land have been undermined in such manner that where the surface has not already subsided it is liable to do so. In London and some other large towns and cities underground tubes and tunnels are from time to time constructed under the authority of Acts of Parliament by authorised private companies or municipalities.

When these burrowings are effected extreme precautions are commonly taken to safeguard the tubes or channels from any danger of collapse from vertical or lateral pressure, and the same structural arrangements which fortify an underground tube against collapse make it yield strong rigid resistance in the shape of support for ground and houses above. A considerable proportion of the multitudinous operations which are continually being carried out in towns and cities have a natural tendency to affect the foundations, and thus the ultimate stability, of houses, and even the passage of heavy steam rollers along the streets cannot fail to have some effect. Often when small injuries are inflicted nothing is seen or otherwise made evident, and when at last something obviously gives way under circumstances which indicate failure of support, it may be next to impossible to prove conclusively that the result is due to any one particular cause to the exclusion of others, or that any particular person is responsible.

CHAPTER II

LIGHT: NATURE OF THE RIGHT

The expression "right to light," though often used, is apt to mislead by engendering false ideas concerning the true nature of the issues, when there are disputes between neighbouring proprietors about windows in houses, whether new or old, and about structures which interfere with the free access of light to those windows.

Really the question at issue when a "light" case comes to trial in a Court of Law is not whether an owner or occupier has a right to open one or more new windows or to enlarge old ones, but whether, under the circumstances of each case, the owner or occupier of the building in which the windows are, has a right to demand that the owners or occupiers of neighbouring land and buildings should not obstruct the light which would ordinarily reach the windows but for the obstruction. Every owner of land is entitled to the free use of all the light which reaches his land, whether it comes vertically or across the land of his neighbours. Also an owner is *prima facie* entitled (subject to any laws or authorised bye-laws or special contracts affecting his rights) to build upon his land where and when he pleases, and to erect any kind of buildings in any position and of any extent and height, and to open just as many windows as he likes, and in any positions. He is under no legal obligation to consult his neighbours when planning his own buildings, and (assuming that his property is not burdened as a servient tenement by restrictive easements in favour of neighbouring properties) his neighbours will have no right to interfere with his building operations, and he cannot be compelled to close or in any way to alter the position or size of any of his windows new or old.

The right of a man to build as and when he likes on his own land is a natural attribute of the ownership of land, and his right to take in light through any openings he may select follows from his natural right to use and enjoy all or any part of the light which reaches his land from any direction.

A neighbour can only acquire a right to object if he can show that the owner, in building, has committed some trespass or other actionable wrong. He must allege and prove either a breach of contract or a "tort" in the nature of a nuisance of which the law can take cognisance. A common ground of objection to new buildings is that they wrongfully obstruct the enjoyment of some easement appertaining to the ownership of a neighbouring tenement.

An easement is a kind of privilege appertaining to the ownership of a particular tenement, which entitles the owner or occupier for the time being, in virtue of his ownership or occupancy, to restrain the owner or occupier of a neighbouring tenement from doing anything to interfere with the enjoyment of the privilege.

An objector who sets up an easement claims to be especially privileged in so far as he sets up claims which, if established, will give him a right to restrain the free and full enjoyment of his natural rights by a neighbouring owner. For example, a neighbouring owner or occupier may say to the person building, "there have been windows in certain definite positions on my property to which light has passed uninterruptedly across your land for more than twenty years, and I have a prescriptive right to restrain you from interfering with the light which would reach my windows but for your action in building so as to interrupt the free flow of light to these windows." He thus claims dominant rights for his tenement over the neighbouring tenement.

Most disputes about "light" between owners of neighbouring properties take the form of disputes about an alleged right to have free access of light to particular window spaces from across a neighbour's land.

In the absence of specific contracts restricting the natural rights there can be no dispute about the right of an owner to open windows in his own tenements, but only about a right to stop light *en route* to particular places.

An easement to uninterrupted light can only be claimed with reference to windows in buildings. There can be no light easement for a piece of open ground which has never been built upon, so that although, as before stated, the owner of the open land can freely use and enjoy all the light which reaches it at any time, he cannot restrain his neighbours from erecting buildings all round which may have the effect of diminishing to any extent the total light which can reach his open space. It has been held that an easement of light cannot be acquired by prescription for an open saw pit. It has also been held that a built-up open structure of scaffolding, or open floors, or stages supported on piles, was not such a building as to support a claim for easement of light. Usually a definite covered building with definite openings or windows to admit light are necessary before any claim for ancient lights can be established, although the right

may be preserved even after the demolition of the original buildings for the benefit of other buildings to be erected on the same site.

Until some definite easement rights have been acquired, all neighbours are on an equal footing as regards their rights to build; and while they may all open any windows they please, as before stated, they may also all build as they like and block each other's lights to any extent, provided, of course, that they do not so build as to trespass on their neighbour's land by overlapping or by any other means.

If next-door neighbours build in opposition to each other, he who builds the highest is able to obtain the greatest quantity of light, and ultimately to obtain an easement of light over neighbouring properties, unless the neighbours are able in time to run up walls or screens so as to block the higher windows which face over their land.

With reference to what has been said about the right of every owner to open windows anywhere he likes on his own property, it is important to know that the neighbours cannot acquire any legal right to restrain the opening of any window on the ground that privacy will be invaded by people looking through the window into their gardens or other places within their tenements which they would like to keep private.

Such invasion of privacy is not recognised as an actionable wrong, so that if the people affected cannot erect screens on their own grounds to stop the overlooking, and thus preserve privacy, there may be no alternative but to submit to the annoyance.

Also, it must be understood that an easement of light does not confer a right of prospect,—or in other words, there is no easement of view or prospect, so that a neighbouring owner or occupier of land may plant trees or hedges or erect buildings in positions which will more or less entirely shut out distant view, if he does not at the same time diminish to an actionable extent the quantity of light which can reach the window. In this connection it may be noted that the amount of light which may reach a window by reflection from a distant landscape is generally a very exceedingly small proportion of the light reaching the window from the sky, and if the physical geography of the neighbourhood permits, the prospect may often be blocked or otherwise spoilt without any actionable invasion of the easement. No question of any right to uninterrupted prospect can arise except under some kind of special contract binding upon the obstructor.

From what has been already said it can be understood how easily neighbouring landlords and householders may cause great inconvenience and annoyance to each other, and real injury to the value of each other's tenements, while keeping within their strictly legal rights. It will also be evident how the possession of an easement of light by one tenement may confer an immense advantage and create a corresponding disadvantageous condition for neighbouring tenements not similarly favoured. It is therefore most important for nearly all persons proposing to deal with house property to take careful note of all easements of light, and to remember that an easement, by its very nature, appertains to the tenement to which it belongs, and is inseparable from it, so that when the tenement is transferred from one owner to another the easement is transferred with the tenement, and the owner for the time being can claim and enforce the privilege. The easement is said to run with the land.

Owners of neighbouring properties may make personal contracts with each other, and they may be personally bound by their contracts, and also some other persons deriving title from them may in certain events be bound by those contracts, when affected with notice under circumstances from which it may fairly be held that they had adopted the contracts; but in a general way mere personal agreements between neighbours to abstain from interfering with each other's privacy or prospect, or in other ways to consult each other's convenience when building or altering their tenements, will not of themselves suffice to secure the properties from the accrual of rights of easement which may more or less seriously hamper the same or other owners in future, and cause ultimate depreciation of the value of the property.

For a full understanding of the nature of the right, it is necessary to take note of the peculiar characteristics which distinguish light from other easements. In the first place, it is what is called a Negative Easement, which does not confer on the owner or occupier of the dominant tenement any sort of right to enter upon any portion of the servient tenement to do anything there. The dominant owner is simply entitled to receive the light upon his own land through the particular openings or windows for which he has acquired an easement or special privilege, as before explained. As with other easements, he cannot require the servient owner to do anything to help him to obtain the light he wants, or indeed to do anything at all. He can only require that his neighbours shall not illegally interrupt the access of light to his privileged window spaces.

Also, the owner whose building receives light is under no obligation to provide for its passing out again. The light is received for use, and may, if desired, be all used up. It is drawn from the common universal stock from which all men are entitled to help themselves whenever they can do so without trespassing upon their neighbour's rights. Evidently, from the very nature and distribution of light through space, any quantity which could be taken in through any window or any definite number of windows would be altogether inappreciable by comparison with the total quantity of light available for the rest of mankind. There can therefore never be a question of injury to anybody from the quantity of light taken in and consumed, any more than any one could complain of injury from the consumption of oceanic water in the boilers

of ocean-going steamers. But although no one can legally complain of the quantity of light received or used, any neighbour is entitled to dispute a claim to restrain his actions in building upon his own land. It is open to a neighbour whose conduct is complained of to deny that any easement has been acquired or remains in existence at the time, or to say that under the circumstances he has not given to plaintiff any just cause of complaint. As before stated, if no easement over his land for any particular openings or windows could be proved, the neighbour would be under no obligation to let any light pass over his land to the windows ; but if an easement over his land were proved, he must then certainly let some light pass, and regulate his building operations accordingly, but it would still be an open question how much light he must let pass across his land. Disputes concerning the extent of the right have been very numerous, and there would seem to have been considerable variations from time to time, and consequent apparent uncertainty about the principles applicable for the decision of such cases. Considerable differences in the facts alleged and proved in different cases, and more particularly some peculiarities in the wording of those sections of the Prescription Act which relate to Light, have been in the main responsible for such apparent conflict of authority.

The law relating to the extent of the Right of Easement to Light is now authoritively determined by the judgments delivered by Lord Chancellor Halsbury and Lords Macnaghten, Davey, Robertson, and Lindley in the House of Lords appeal case—Colls *v.* Home & Colonial Stores Limited—which was finally decided on 2nd May 1904, and reported in Law Reports House of Lords Appeal Cases, pp. 179–213. In that case the facts (so far as it is necessary to set them forth in this place) were these.

The Home & Colonial Stores Limited were lessees of a building with ancient lights facing across Worship Street, Shoreditch. The building was used by them for business purposes. Colls, the defendant in the action and appellant in the House of Lords, proposed to build on the opposite side of the street. The building he proposed to erect was to be 42 feet high. The street was 41 feet broad at that place. The sills of the lowest windows in plaintiffs' place of business were 3 feet from the ground. Plaintiffs brought an action for injunction before the proposed building was erected, because they thought it would obstruct their light. The action was tried by Joyce, J., who found on the evidence that the proposed building would not materially interfere with the access of light to any of plaintiffs' windows, except two out of five windows on the ground floor facing Worship Street.

The room to which those windows belonged was used by plaintiffs as an office for clerks. It was 12 feet 10 inches high and 50 feet deep from the windows to the back, where there were no windows, so that it had been the practice to use electric light for the back part of the room even in the daytime.

The proposed building would not affect the value of the premises, and they would still be sufficiently lighted for all ordinary purposes of occupancy as a place of business.

Joyce, J., dismissed the action with costs. His decision was reversed by the Court of Appeal (Vaughan-Williams, Romer, and Cozens Hardy, L.JJ.), who granted an injunction to restrain the appellant from building so as to darken, injure, or obscure any of the respondents' ancient lights or windows, as they were enjoyed previously to the taking down of the old building at 44 Worship Street, with an order to pull down all the building which had been rebuilt so as to darken, etc.

This last part of the order was consequent upon the fact that, after Joyce, J., had decided in his favour and dismissed the action, defendant had gone on with the erection of his proposed building, and completed it before the decision of the Court of Appeal. On the facts found by Joyce, J., all the learned Lords concurred in finding that no cause of action was disclosed, and they upheld his original decision. The chief principles authoritively affirmed by the House of Lords in that case may be thus summed :—

(1) That the dominant owner is not necessarily entitled to claim a perpetual right to *all* the light which has reached his windows, so as to have a good ground of action if his neighbour intercept some of it.

(2) That to constitute a ground of action there must be such substantial deprivation of light as to make habitation uncomfortable in the case of a dwelling house, or in the case of business premises to prevent the plaintiffs from carrying on his business as beneficially as before.

(3) The test of the right of redress by action is whether the obstruction complained of is a nuisance.

Their Lordships had under consideration all previously reported cases which appeared to have any bearing upon the main questions laid before them for final decision in this case, and they have in effect affirmed that the principles of law now applicable are the same as before the Prescription Act was passed, and they have finally reaffirmed the principle of law enunciated by Lord Hardwicke more than seventy years ago, when he said: "It is not sufficient to say it will alter the plaintiffs' lights, . . . the law says it must . . . be a nuisance."

Thus it may be taken that before any owner or occupier of premises for which the privileges of ancient lights are claimed by prescriptive right can hope to succeed in establishing a ground of action, he must be in a position to prove—(1) That he is entitled to assert dominant rights for his tenement over the land owned or occupied by the person whose action in building or otherwise obstructing his lights is complained of. (2)

That the action complained of really does cause a substantial diminution of the light which can reach the privileged windows. (3) That that substantial diminution of light is so great that the channels left free for light to reach the window will not be sufficient for the comfortable enjoyment of the premises if the new building complained of is erected or allowed to remain without alteration; or, That the privileged premises can no longer be beneficially used as before in consequence of the action of defendant in building so as to obstruct part of the light to the windows.

It is practically impossible to lay down any exact hard or fast rules to bind a Court or Jury in deciding the issue about the sufficiency of the obstruction to constitute a ground of action in all cases of dispute.

A good general working rule which has been often applied and approved and accepted has been that if a clear 45 degrees of vertical angle is left unobstructed, the privilege of ancient lights is generally thought to be sufficiently safeguarded.

This means in practice that the height of the obstructing building must not exceed the horizontal distance between the two buildings by any more than the height of the sill of the lowest privileged window.

This common rule of practice is not, however, to be regarded as a binding rule of law.

In each case a number of circumstances may have to be taken into account to lead to a just decision, which shall secure to the owner or occupier of the privileged tenement all that he may reasonably be held entitled to continue to enjoy without imposing any greater burden on the servient tenement than the circumstances of the case strictly require.

Subject to what has been said already, the broad general questions to be determined in each case are—(1) Whether the ancient lights of the plaintiff (or person complaining) have been *illegally* obstructed. (2) If so, what damage has been sustained in respect of the injury. For arriving at a just decision all relevant circumstances may be and should be taken into account.

All available sources of light should be considered, and it is nearly if not quite as important to know what is left as what is stopped by the building complained of.

Also the locality and the necessities as regards light for the windows of the dominant tenement, in order that it may be profitably or conveniently used for the purposes for which it is evidently designed may be considered. Special priviieges for extra light in excess of what would ordinarily be presumed to be reasonable could only be allowed in cases where special circumstances could be proved, such as particular covenants actual or implied, or some special agreement to cover the excess claim.

In a general way it is not to be presumed that owners or occupiers of servient tenements are affected with knowledge of how the light is used after it has entered the windows of dominant tenements, or that they are concerned about any changes which may be made inside the building. It is a general rule that extra burdens should not be imposed upon servient tenements or their owners or occupiers without their consent, but facts from which consent may be presumed may often be proved.

The space available would not admit of any attempt to analyse or even to pass in rapid review the chief facts proved in the many reported cases which have been decided from time to time in the Law Courts, nor would any commensurate advantage be derived from any such attempt, because the facts and evidence of no two cases are exactly alike, and in some of the reported cases the judicial views of the principles applicable have not always been uniformly consistent.

A very large proportion of "Ancient Light" disputes are essentially matters for compromise, due regard being had for the comfort and convenience and legal rights of all persons concerned.

The legal rights are not in their nature sharply definable by any exact bounds. Lord Chancellor Halsbury, in his judgment in Colls *v.* Home & Colonial Stores, after saying that "*The test of the right is, I think, whether the obstruction is a nuisance*," goes on to say, "and it appears to me, the value of the test makes the amount of right acquired depend upon the surroundings and circumstances of light coming from other sources, as well as the question of the proximity of the premises complained of. What may be called the uncertainty of the test may also be described as its elasticity." Nearly all questions which may legitimately arise are of such a character that, with a right disposition on the part of the principal persons concerned, they can be best settled by inspection, inquiry, and consultation with experienced surveyors and architects. When light actions are tried in a Court of Law the issues are for the most part issues of fact, which would be determined by a Jury if there were one, or by the Judge acting as a Jury.

In a Court of Law the issues of fact are determined mainly by aid of plans, and the opinions and estimates of experts and others called to give evidence in Court by the opposing parties. In many cases it would be more satisfactory if the main issues of fact could be ascertained and determined on the spot by competent professional assessors, or even by experts appointed by the parties and vested with responsibility to act as judges of fact and as arbitrators, rather than as partisans in a Court of Law.

It is, however, necessary that in all cases due regard should be had for the legal rights of the parties, otherwise there might be much haphazard injustice and confusion.

In concluding this chapter it may be as well to restate in epitomised form the chief principles of law affecting the nature and extent of the "Easement of Light."

(1) Every owner of land has a *primâ facie* right to

build on it, and to open any windows he pleases in any part of his buildings, and he has a free right to receive and take in and to use all the light he can get from any or every direction.

(2) *Prima facie* all neighbours have the same rights in these respects, so that if they choose to exercise their rights to build without consulting each other's interests or convenience or comfort they may hem each other in so as to make many or most of the windows useless; or if they like they may run up blank walls or erect hoarding or plant trees or hedges close to the borders of their land for the express purpose of obstructing the light to a neighbour's windows

(3) Sometimes a privilege is acquired for some windows in a covered building which entitles the owner or occupier of the premises to restrain neighbours from so building as to interfere with the privilege.

The privilege is called in law an Easement.

The tenement with the privileged windows is called the "dominant" tenement, and its owner the "dominant" owner. The privilege overrides and restrains the exercise of some of the natural rights of one or more neighbours. The tenements whose owners or occupiers are restrained from the exercise of their full natural rights because of the privilege attached to the windows are called "servient" tenements, and the owners "servient" owners.

(4) The privilege of the dominant implies a burden on the servient tenement One is benefited, the other is injured, by the existence of the easement.

When, therefore, a dispute arises between neighbours about an easement of light for particular windows, it may be necessary first to ascertain whether a claim for any privilege is well grounded; and if it is found to be so, then the extent of the privilege should be inquired into, with due regard to the principle that no excessive burden should be imposed on the servient tenement or its owner or occupier without the consent of the servient owner clearly established.

(5) The general rule is that a prescription privilege (or Easement of Light) covers only so much light as is reasonable under the circumstances of the case, and the test to be applied when the action of a servient owner or occupier in building or otherwise diminishing the supply of light to the privileged window comes up for consideration and decision is whether his action is of such a character as to constitute a nuisance.

Very small or unsubstantial interference with light to a privileged window will not suffice for a ground of action, on the general principle *de minimis non curat lex*, and even substantial interference with the lighting of privileged windows may not necessarily suffice to give a ground of action; there must be in addition real substantial injury to the person complaining, or to the value of his property.

(6) The privilege does not confer any claim for a good outlook or prospect from the windows, nor any right to demand an uninterrupted view towards the windows from the side or in any other particular direction. It is concerned only with the access of a reasonable sufficiency of light to the windows

CHAPTER III

LIGHT: ACQUISITION OF THE RIGHT

The ordinary means by which an easement of light can be obtained are by grant or covenant, express or implied, or under the provisions of the Prescription Act, 2 & 3 William IV. c. 71.

Theoretically, all easements may be considered as founded on grant or covenant, according as they are positive or negative in their nature.

The theory is that a dominant owner could not legally acquire a burdensome right over a servient tenement unless the owner of that tenement had voluntarily burdened his estate with the easement.

When the easement is positive, such as a "Right of way," for example, the owner of the tenement over which it is intended to create a "right of way" may create that right in favour of the owner of another tenement by a deed of grant; or if the easement to be created is a negative one, such as an easement of light or air, the owner of the land across which the light or air passes binds himself by covenant in a deed not to do acts which will interrupt the access of light and air to buildings on the land of another. In either case a relationship of dominant and servient tenements and owners may be thus created, and the general principles of law applicable to the subsequent rights of all parties who may be, or afterwards become, owners or occupiers of the tenements will be the same.

It is well, however, to keep in mind the general distinction between those easements which are classed as positive and conveyed by grant, and those which are negative and reserved by covenant.

The positive easement implies a right for a dominant owner to make active use of the land of another by doing something on, or in, or under the land, as of right, which would ordinarily be acts of trespass, and the right to do things can be conveyed by deed of grant; whereas the negative easement does not confer any active rights on the owner of the dominant tenement, and all that the dominant owner requires is that the servient owner or persons deriving title from him shall not do certain things which under ordinary circumstances he or they would be entitled to do. The servient owner must therefore be bound by covenant to abstain from doing what would otherwise be lawful acts. In either case it is the servient owner who must execute the grant or be bound by covenant. Except by Act of Parliament, no other person than an owner can voluntarily create an easement over land to run with the land and to be a burden upon it for ever; but other persons in possession and holding subordinate interests, such, for example, as a life interest or a long lease, may bind themselves and the land to the extent of their interest, but not beyond, while even an owner of the fee who has parted with possession of his tenement on long lease cannot create easements over his property to the prejudice of the tenant in possession under the lease.

Sometimes owners or occupiers of neighbouring tenements enter into parole agreements relating to what they will and will not do for each other's comfort and convenience, or for mutual advantage, and such agreements are not infrequently reduced to writing and signed by the parties. In such cases the parties may be bound as by any other ordinary agreements, and if the agreement in any case is of such a character as to amount to an agreement to grant an easement, the other party may be able, on the strength of it, to compel the subsequent execution of a proper deed to create an easement; but it is important to bear in mind that mere agreements or contracts not under seal cannot create an easement, and the utmost they can do is to confer a personal right to demand a regular deed to bind the land, or a right of action for breach of contract if the terms are not observed by the parties bound by them.

The benefit of mere personal contracts may be lost when the tenements pass into the ownership or possession of strangers.

The acquisition of easements by particular description in a deed is the most satisfactory of all methods, and the least likely to favour subsequent disputes or litigation.

An easement may also have been acquired under the general words in an old deed of conveyance, or, when land is transferred under the Conveyancing and Law of Property Act, 1881, all easements appurtenant to the land at the time of transfer will be conveyed with the land without the use of any particular description or general words. This Act only came into operation after the 31st December 1881, and therefore all easements to be conveyed needed to be described by particular description or general words before that date.

It is not thought necessary to attempt to enumerate or discuss the technical rulers of law and practice affecting the drafting and interpretation of deeds by which easements are or may be created or transferred.

Any such attempt would lie outside the general range and intention of this work, and require more space than can be spared.

Professional advice and assistance are nearly always necessary, or at least desirable, in the interest of parties concerned when deeds of conveyance or express grants or particular covenants need to be drafted or considered or interpreted, and little if any good would result from attempting to deal with such matters here, even if space did permit.

There is, however, one general principle of great importance to be always remembered, which is, that *A grantor may not derogate from his own grant.*

The application of this principle will often be of much assistance to grantees of property, by enabling them to use, and preserve as easements, rights which have not been specifically granted, but the enjoyment of which could not be prevented by the grantor without derogation from some grant.

What are called *implied grants* of easements in favour of the grantee frequently arise out of actual grants or conveyance of houses. A grant of supplementary easements over the land of the grantor will often be presumed in favour of a grantee, to assure to him the full value and use of his grant as against the grantor, but very rarely indeed will it happen that any sort of reservation (or grant by the grantee) will be implied in favour of the grantor of property.

As a general rule, when land or an easement is conveyed by deed, the grantee derives title by implied grant to any easement affecting the land of the grantor which is necessary to secure to the grantee full enjoyment of the land or easement granted.

There is a presumption that at the time of the original grant it must have been the intention of the parties that the grantee should have the means of using and enjoying the thing granted, and therefore that he should have all rights and powers over the land of the grantor which might be necessary for the full use and enjoyment of the subject matter of the grant.

This principle is often applied to cases where a man who owns neighbouring land and houses sells the houses or land separately, retaining some portions of his estate while transferring others, or sometimes when a man sells different parts of his estate at the same time to different owners, or when he directs a partition of his land and house property by will.

Easements of light may be created by implied grant, on the principle above enunciated, in favour of purchasers of separate houses from builders or other persons who have one or more houses to dispose of, and contiguous land not covered with buildings.

If a man, having a house and land, sells the house and keeps the land, there is ordinarily an implied grant of an easement of light over his land for the windows of the house sold, or an implied covenant not to obstruct, so that he cannot afterwards build on the land retained in his possession in such a manner as to obstruct the windows or any of them to an actionable extent. It is a presumption of law that, in selling the house with windows, he and the purchaser must have intended that the windows should be usable after the sale as before ; and having sold the house with windows in it, the original owner could not afterwards derogate from his grant or violate his implied covenant by making the house less valuable or comfortable to live in by obstructing the lights.

If the original owner wanted to reserve a right to build in a particular way on the land retained, so as to substantially diminish the light which could reach the windows of the house sold, or any of them, there should have been an express reservation in the deed of conveyance of the right to so build.

If the vendor could not, after selling the house, build on his remaining land so as to block any of its lights, it follows that a subsequent purchaser of the land also could not be allowed to obscure the lights. The purchaser could not acquire a better title than his vendor.

It is necessary, however, to note that, although an implied covenant not to obstruct the windows may be presumed against the vendor of a house who has not specifically reserved a right to build on the adjacent land, it is possible in some cases to adduce evidence from which the presumption of an implied covenant can be rebutted. In several cases it has been held that all surrounding circumstances must also be taken into consideration.

For example, suppose an estate were being developed by being laid out and built over in accordance with a definite prearranged plan, and a man were to purchase a new house on one side of an unfinished street after studying the plan of the proposed building operations, he could not afterwards be allowed to object to the erection of buildings on the opposite side of the street in which his new house was situated ; at least, he could not do so if the buildings opposite were such as he had been informed were intended to be erected in accordance with the settled plan.

The grant of light in such a case must be taken to be such light as he would have after the contemplated buildings, of which he had prior knowledge, should have been erected.

Suppose, again, that instead of adhering to the original plan of building operations, the vendor should change his mind after the original sale of the house, and wish to build taller houses on the opposite side of the street, the purchaser might have just ground of complaint, because an implied covenant to leave his lights unobstructed except by buildings of the kind contemplated at the time of purchase would have been broken.

When implied covenants are in question there may easily be much ground for dispute concerning what exactly has to be implied.

These cases of implied covenants which operate as

grants of easements of light arise commonly out of conveyances under the Conveyancing Act. The circumstances of different cases may vary to an indefinite extent, and each case of dispute must be adjusted on its individual merits. Among other circumstances which may need to be taken into account may be the nature of the vendor's agreement with the freeholder, when he is not himself the freeholder.

In one case it has been held that a reference in the conveyance and a plan to adjoining land as "building land" did not suffice to deprive a purchaser of the benefit of an "implied covenant" for unobstructed lights at the side of a building he has purchased. It has been held also that a mortgagee, selling a house under a power of sale and reserving the adjoining land which was included in the same mortgage, had power to grant an implied covenant for light as if he were absolute owner in his own right.

When a man owns house and land, and sells the land while retaining the house, the presumption is that he sells the land unburdened by any easement of light, so that the purchaser may, if he pleases, build close up to the margin of the land purchased, and may thus block any or all of the windows in the house. Here the vendor, if he had chosen to do so, might have refused to sell the land unless the prospective purchaser would consent to execute a covenant not to obstruct any of the windows of the house; but, having conveyed the land without any express restriction, or without obtaining at the same time a definite grant of easement rights from the vendee, it must be taken that in conveying his land to the purchaser it was mutually intended that the land should be conveyed free of all burdens so far as the vendor was concerned.

A third class of cases is where the owner of house and land sells them separately and simultaneously to different purchasers. In such cases it has been held that the rights of the purchasers are practically the same as if the house had been sold first and the land at a later date. Thus the purchaser of the house gets a permanent easement for his windows in the house, and the purchaser of the land acquires it subject to the burden of that easement.

If two or more houses are sold simultaneously to different purchasers, and each house enjoys light coming over the ground of the other, an easement of light is impliedly granted to each, so that neither purchaser can block the light of the other.

Sometimes it happens that an owner desires to divide up his property after his death, and he provides for the severance of houses and land by his will. In such cases it has been held that the will operates as a simultaneous conveyance of the house and land to two devisees, and the devisee of the house would take it with a right to enjoy the window light substantially as it had been in testator's lifetime, and the devisee of the land would take the land subject to the burden of an easement in favour of the windows of the house.

It may be taken as a general rule that, when house property or land is conveyed by deed, all manifest and apparent easements are to be taken to be conveyed with the property, so far at least as it is in the power of the vendor or grantor to grant them to the purchasers.

A conveyance under the Conveyancing Act will carry not only all easements over properties which were servient to the property conveyed at the time of conveyance, but also such quasi-easements as might have been enjoyed over the land of the vendor unless such quasi-easements be specially excepted and reserved.

The expression quasi-easement as here used means such advantage in the nature of an easement as one portion of the vendor's estate may enjoy with reference to another portion.

Acquisition of right to light by prescription is in these days governed by the Prescription Act, which came into operation at the commencement of the Michaelmas term, 1832.

The portions of the Act which have any relation to light are the Preamble and Sections 3, 4, 5, and 6, the exact text of which is as follows:—

"Whereas the expression 'time immemorial or time whereof the memory of man runneth not to the contrary,' is now by the law of England in many cases considered to include and denote the whole period of time from the reign of King Richard the First, whereby the title of matters that have been long enjoyed is sometimes defeated by showing the commencement of such enjoyment, which is in many cases productive of inconvenience and injustice," for remedy whereof be it enacted. . . .

"Section 3. That when the access and use of light to and for any dwelling-house, workshop, or other building shall have been actually enjoyed therewith for the full period of twenty years without interruption, the right thereto shall be deemed absolute and indefeasible, any local usage or custom to the contrary notwithstanding, unless it shall appear that the same was enjoyed by some consent or agreement expressly made or given for that purpose by deed or writing.

"Section 4. That each of the respective periods of years herein before mentioned shall be deemed and taken to be the period next before some suit or action wherein the claim or matter to which such period may relate shall have been or shall be brought into question, and that no act or other matter shall be deemed to be an interruption within the meaning of this statute unless the same shall have been or shall be submitted to, or acquiesced in for one year after the party interrupted shall have had or shall have notice thereof, and of the person making or authorising the same to be made.

"Section 5. And be it further enacted, that in all actions upon the case and other pleadings, wherein the party claiming may now by law allege his right generally, without averring the existence of such right from

time immemorial, such general allegation shall still be deemed sufficient; and if the same shall be denied, all and every, the matters in this Act mentioned and provided, which shall be applicable in the case, shall be admissible in evidence to sustain or rebut such allegation, and that in all pleadings to actions of trespass, and in all other pleadings wherein, before the passing of this Act, it would have been necessary to allege the right to have existed from time immemorial, it shall be sufficient to allege the enjoyment thereof as of right by the occupiers of the tenement in respect whereof the same is claimed for and during such of the periods mentioned in this Act as may be applicable to the case, and without claiming in the name or right of the owner of the fee, as is now usually done; and if the other party shall intend to rely on any proviso, exception, incapacity, disability, contract, agreement, or other matter herebefore mentioned, or on any cause or matter of fact or of law not inconsistent with the simple fact of enjoyment, the same shall be specially alleged and set forth in answer to the allegation of the party claiming, and shall not be received in evidence on any general traverse or denial of such allegations.

"Section 6. And be it further enacted, that in the several cases mentioned in, and provided for by this Act, no presumption shall be allowed or made in favour or support of any claim, upon proof of the exercise or enjoyment of the right or matter claimed, for any less period of time or number of years than for such period or number mentioned in the Act as may be applicable to the case and to the nature of the claim.

"Section 10. And be it further enacted, that this Act shall commence and take effect on the first day of Michaelmas term now next ensuing."

It will be seen that the general object of the Act was "for shortening the time of prescription in certain cases." The Act was not intended to, and did not in fact, alter the substantive law concerning the nature and extent of rights to light, although at one time it was thought that it did, but it has provided means and prescribed circumstances and conditions under which rights to an easement of light may be acquired.

Section 3 of the Act relates exclusively to light, but it must be read in connection with Section 4, so that while Section 3 enacts that, in order to acquire an "absolute and indefeasible" right to light, access, use, and actual enjoyment "for the full period of twenty years" are necessary; Section 4 provides in effect that the "full period of twenty years shall be deemed and taken to be the period next before some suit or action wherein the claim . . . shall have been or shall be brought into question."

It is not just any period of twenty years of uninterrupted use and enjoyment which will satisfy the requirements of the Act, but the particular period just before such suit or action is started in which the claim to light is brought in question. It is not essential in all cases that the time should be counted backwards from the particular suit then before the Court, if there has been any prior suit or action in which the matter was brought in question, though naturally, in the great majority of ordinary cases, the twenty years immediately preceding the institution of the particular suit or action then pending will be the time during which uninterrupted enjoyment must be proved.

The important point to notice concerning access, use, and enjoyment of light is that no amount of time, however great, will of itself confer any complete right under the Act. The right is at best what has been called an inchoate right until some suit or action has been instituted, when it may become absolute and indefeasible if the uninterrupted use and enjoyment for the immediately preceding twenty years are proved.

It follows therefore from what has been just stated that when a neighbour puts up structures upon his own land which obstruct lights to his neighbour's windows, he is acting *prima facie* within his rights, so far at least as the Prescription Act is concerned, unless there has already been a law suit concerning those lights; and if he maintains the obstruction for a whole year, the owner of the house with windows cannot afterwards compel the removal of the obstruction or maintain a prescriptive claim for light to those windows.

If windows have not been in existence for a full twenty years before they are obstructed, he cannot sue for the removal of obstruction, because he has not even an inchoate right to an easement, and only at best a bare chance of acquiring such a right. If, however, he has enjoyed the uninterrupted access and use of light for a full twenty years, he has acquired such right, and any time within a year of the obstruction he may institute an action and allege and prove his inchoate prescriptive right, which will then become absolute and indefeasible, after which he can obtain all appropriate legal remedies to protect his absolute and indefeasible right,—as, for example, by recovery of damages, or by ordinary or mandatory injunction get rid of the threatened or actual nuisance affecting his rights.

The mere opening of windows in a building and keeping them in a state and condition such that it can be held that the owner has had access and use and enjoyment of light for a full period of twenty years would ordinarily suffice for the development of an inchoate right, such as could be made absolute at any time thereafter, provided, of course, that they were not abandoned or obstructed in such fashion as to destroy the right.

It is possible, however, to provide against an accrual of an easement of light by access, use, enjoyment, and efflux of time followed by suit, by providing specially for the enjoyment "by some consent or agreement expressly made or given for that purpose by deed or writing."

The meaning of the expression "actual enjoyment" in Section 3 has been discussed in several reported cases, and it is apparently settled that "actual enjoyment" does not necessitate or imply continual use. Intermittent use is sufficient. Windows may be temporarily closed by shutters, and only occasionally opened for special purposes at more or less distant intervals of time, or they may be partially covered up by shelves, without the owner losing the benefit of "actual enjoyment" as provided in the Act; but when windows had been boarded up internally for several year it was held that there had been no actual enjoyment during that time. Enjoyment is a question of fact to be decided in each case according to the particular circumstances.

In one case it was questioned whether there could have been actual enjoyment within the meaning of the statute when a house had been built and windows put in and roof put on, but the inside left in such condition that the house was uninhabitable, or in fact uninhabited, during the whole prescription period of twenty years before suit.

It was held that under such circumstances the statute is satisfied, and that no personal occupation is necessary to constitute "actual enjoyment" within the meaning of the Act. Concerning the commencement of the prescription period of twenty years, questions may sometimes arise. In the case of new windows in an old building, time may ordinarily begin to run in favour of that window from the time it is first put in, and in the case of new building from the time the shell of the building is covered in by a roof, assuming, of course, that the window spaces are there at the time.

The meaning of the term "interruption" in Section 3 of the Act is explained in Section 4. "No act or other matter shall be deemed to be an interruption within the meaning of the statute unless the same shall have been or shall be submitted to, or acquiesced in for one year after the party interrupted shall have had or shall have notice thereof, and of the person making or authorising the same to be made."

Interruption means some obstructive act by somebody other than the person whose lights are obstructed, and should be of such character as to stop enjoyment. The words "without interruption" in the Act do not mean "without intermission." Before the passing of the Prescription Act there was an established custom in the cities of London and York under which owners of houses or of ancient foundations in either city might build to any height upon the old foundations, or raise existing houses to any extent, without regard to the way in which light to neighbouring houses would be interfered with by the new building.

The Prescription Act overrides that custom, and in effect destroys it, because it gives an absolute and indefeasible right to unobstructed light under conditions prescribed by the Act—"any local usage or custom notwithstanding."

It is important also to note that, as regards light, no right to an easement can be acquired against the Crown under the Act. Other easements referred to in other sections of the Act can be acquired over Crown Lands as over lands of private owners, but all reference to the Crown is omitted from Section 3 of the Act, and as a consequence the Act does not apply to Crown Lands.

It follows, therefore, that not only can no prescription right to light under the Act be acquired against the Crown, but also no matter how long windows overlooking Crown Land may have been used and enjoyed, a purchaser from the Crown can build so as to obstruct light to those windows at any time within twenty years from the date of his purchase.

Of course, the Crown may make grants of easements of light by covenanting not to obstruct, or may enter into agreements relating to building on its own or neighbouring estates, but in the absence of any special deed or agreement by which the natural rights of the Crown may be restricted or an easement created, the general presumption is that Crown Lands are not servient to neighbouring tenements for light.

Also it may be noted that Section 3 of the Act does not require that there should be any claim of right while the prescriptive period is running. While, therefore, such easements as rights of way and water referred to in the second section of the Act must be enjoyed during the prescriptive period as of right (and not by permission or licence or in return for rent or fees paid for the enjoyment), in order to obtain the benefit of the Act to establish an easement, it is sufficient in the case of light if it is enjoyed during the period of twenty years, even though the enjoyment appears to be permissive, or if regular payments are made during the prescriptive period in consideration of the neighbour whose land is overlooked not objecting or interfering with the flow of light to the windows.

It is, however, necessary that the light should have been enjoyed after passing over the land of some owner other than the person enjoying the use of the light. An owner cannot acquire an easement over his own land. Rights which might amount to an easement over the land of another would only be part of the natural proprietory rights of the owner of the house and land. He could, if he liked, at any time so build on his own land as to obstruct any light going to any windows in his own house, or he could leave them unobstructed, but no amount of time would confer any privilege or inchoate right under the Prescription Act so long as the land and house were owned by the same person.

The intention of the Act is to define the law as regards the acquisition of prescriptive rights as between neighbours who may have conflicting interests, and to remove causes of dispute and injustice.

CHAPTER IV

LIGHT: DISTURBANCE, REMEDIES, AND EXTINCTION

Disturbance and Remedies, generally speaking, when an easement exists, whether that easement has come into existence by express or implied grant or covenant, or by prescription under the Act, whoever has a right to enjoy that easement is entitled to sue for damages or injunction, or both, for disturbance or interruption of the enjoyment, or for an injunction to prevent a threatened disturbance.

In former days the ordinary remedy for an actual disturbance of an easement right was by action at law upon the case, and damages were the common remedy, with a subsequent appeal to Courts of Equity "to grant an injunction in aid of the legal right where there was danger of irreparable mischief, or where an injunction was required to prevent multiplicity of actions." Since the passing of the Judicature Act the High Court has had all the jurisdiction of the Court of Chancery and of the Courts of Law, and it has become the practice to seek equitable remedies for these cases almost as a matter of course, but it is important to bear in mind that for the most part the matters in dispute are matters of fact, suitable for a jury to decide, including an estimate of the amount of damages which would suffice to compensate the plaintiff for the injury done to his legal right. If a good cause of action is established, plaintiff is entitled to remedy in the shape of some damages as a matter of course, which may be either nominal or substantial; but whether he can also obtain relief by injunction depends on the judicial discretion of the Court with reference to the facts of the case. When a disturbance of enjoyment is threatened in the matter of ancient lights, an injunction to restrain the defendant from carrying his threat into execution is ordinarily the appropriate remedy, and would be granted where really substantial injury was threatened; but when no action has been taken by the owner or occupier of a building with ancient lights until the owner or occupier of a servient tenement has completed his building, it must not be assumed that a mandatory injunction to pull down the offending building will be granted as a matter of course. Judges, in the exercise of their judicial equitable discretion, will take account of the injury which would result to a defendant from compelling him to demolish substantial portions of any building which he may have erected in good faith, as well as of the injury which would be inflicted upon plaintiff from letting the building stand. If the plaintiff's conduct has been such as to imply acquiescence in the erection of his neighbour's building, he must not expect to be able to obtain a mandatory injunction to pull the building down.

If a defendant had run up blank walls or screens for the express purpose of blocking plaintiff's windows, for which an easement right had been acquired by any means, then no doubt, on proof of the facts, defendant would ordinarily be compelled to remove the obstructions; but between the two extremes of a person erecting structures intended only to obstruct a neighbour's lights while not otherwise benefiting himself or his property, and the case of a man building with all good faith on his own land for the improvement of his own property without design to injure his neighbour's, there may be many shades of difference in the facts, which need to be taken into account; and judges, dealing with the facts of each particular case, will grant or refuse requests for mandatory injunctions in whole or in part, or on terms, as may appear to be most reasonable and just under the proved circumstances of each case.

It may be noted that, if the enjoyment of light is interrupted, the interruption may cause injury, not only to a tenant in possession, but also to the landlord or to a reversioner, by diminishing the value of his reversionary estate, and in all such cases an action will lie at the instance of any of the persons injured.

Also it may be noted that if an action is brought with a claim for damages only, any damages which may be awarded will relate to injury inflicted before action, that is—to past injury; and if the interruption is continued it is open to the same plaintiff to institute a fresh action for further damages for injury inflicted since the former suit was instituted, and, in theory at least, fresh actions may be started again and again for damages for the same obstruction, but for different periods of time until such time as the defendant may of his own motion abate the nuisance. When, however, the plaintiff has sued for an injunction, and damages have been awarded in lieu of injunction, the damages thus awarded put an end to litigation as regards the particular interruption or obstruction complained of. The damages cover not only the past but the future, and, an injunction having been refused, the defendant can maintain the existing obstruction; but if he afterwards adds to the obstruction anything not contemplated or in existence at the time of action, the added obstruction may give a fresh cause of action if

it causes further injury to the ancient lights of the plaintiff.

When disputes have arisen concerning obstruction to light, various excuses have been put forward at different times with the object of trying to avoid liability for obstruction, but generally without effect. The real question always is, whether the particular structure complained of does, as a matter of fact, substantially injure the plaintiff by diminishing his light to an actionable extent, as previously explained. Sometimes a dominant owner decides to improve his windows so that they may admit more light than before. This he is entitled to do without thereby giving any right to a servient owner or occupier to obstruct; but if he enlarges his windows, or if he opens fresh ones, the servient owner may obstruct the new windows or the enlarged parts of the old ones if he can do so without obscuring those which are old, or the old parts of the enlarged windows.

Formerly it used to be thought that, if a dominant owner enlarged his privileged windows, or opened new ones in their neighbourhood which could not be obstructed without obstruction to the ancient lights also, the servient owner then had a right to obstruct all the windows so enlarged or opened.

The opinion was that, inasmuch as no new or enhanced burden could be created by a dominant owner without the consent of the servient owner, the servient owner could certainly build so as to block what was new, and it would be the fault of the dominant owner in such cases if the enjoyment of his ancient lights was also interrupted and in time lost altogether.

Later, in the case of Tapling *v.* Jones, finally decided on appeal in the House of Lords, it was held that an easement of light acquired under the Prescription Act was absolute and indefeasible, and could not be destroyed or interrupted because the owner had enlarged his old windows and opened new ones which were not privileged.

Lord Chancellor Westbury pointed out that the Act of opening new windows was not a wrongful one, but in law an innocent act, and no innocent act can destroy the existing right of one party or give an enlarged right to the other.

Similarly the right of an adjoining servient owner to build on his own land is neither enlarged nor restricted as a consequence of the opening of any new windows by a neighbour, so that the servient owner may exercise his right to build as he likes, except that he must not build in such a way as to obstruct ancient lights.

Evidently, if a dominant owner can safely go on enlarging his ancient windows and opening new ones, under cover, as it were, of those which are old, he might by degrees better the position of his dominant tenement, and in time impose serious additional burdens on the servient tenement,—if he could in the end maintain as full rights or privileges for the enlarged and new windows as for the old ones.

Courts administering law and equity would not favourably regard such a course of conduct, and if a servient owner were to build so as to obstruct the whole of the light old and new, as the only available means for stopping the accrual of new burdens, it is probable that the dominant owner could not under such circumstances obtain mandatory injunction, but only damages with reference to the ancient lights which might then be lost.

It may be observed that the decision of the House of Lords in Tapling *v.* Jones overruled several prior decisions of the Courts below, and it is not altogether in apparent accord with the later decision of the House of Lords in Colls *v.* The Home & Colonial Stores.

In some future cases it may be argued that the opening of new or enlarged windows overlooking a servient tenement, in directions where windows previously existed, does not necessarily amount to the imposition, or even attempt at imposition, of new or increased burdens upon that tenement; and it may perhaps be further argued that, in accordance with the principles laid down in Colls *v.* The Home & Colonial Stores, the enlargement or multiplication of window space by the dominant owner rather tends to diminish the burden on the servient tenement, because with superabundant lighting through many or large windows in the dominant tenement, it may be possible for the servient owner to build more extensively without reducing the superabundance of light below a point where there will still be enough left for all ordinary purposes of habitation or business.

The true measure of the burden imposed on the servient tenement is the amount of restriction to which he must submit when he wants to erect buildings, etc., on his own land, and he has no grievance unless that restriction is increased, nor has the dominant owner any real grievance unless his lights are obstructed as to leave him in a worse position as regards the lighting of his premises than he was in before opening or enlarging his windows.

Extinction, Suspension, and Revival

When one person becomes seized in fee of both the dominant and servient tenement, easements of light and all other easements are extinguished absolutely as regards those estates.

When one person becomes owner of dominant and servient tenements, for different estates in each, the easements are only suspended during unity of ownership and revive again on severance.

Easements may also be extinguished by release or abandonment by the dominant owner. A regular formal abandonment must be by deed, for a deed being necessary to create an easement by grant or covenant, so a deed is necessary to destroy one; and just as the servient owner was the only person who could create

an easement over his property by a deed or grant to the dominant owner, so a dominant owner is the only person who can extinguish an easement by a deed of regrant to the servient owner.

Similarly, as a grant may be implied under circumstances such as were referred to in the last chapter, so a regrant or release may sometimes be implied from circumstances. Non-use, coupled with other evidence of intention to abandon, may under some circumstances justify a conclusion that an easement has been abandoned, but mere non-use for some time will not ordinarily suffice to prove abandonment.

A class of case in which a doubt may often be raised whether an easement of light has been abandoned or not is where buildings with ancient lights have been demolished.

There can, of course, be no use or enjoyment when there is no building in existence, but the dominant owner may intend to rebuild, and to do this in such manner as to make beneficial use of the privilege of ancient lights which had been acquired for the demolished building. Sometimes he may set to work to build on the old site without any delay, and he may have all plans and designs for the new building ready in hand before the demolition of the old one ; and the architectural designs for the new buildings may clearly show that he distinctly intends to reopen windows in the new building in the same positions as the ancient lights of the old one.

In such a case there would be no room to doubt that the dominant owner wished and intended to preserve his easement, and, if anyone were to start building on the servient tenement in such fashion as to threaten to obstruct his ancient lights for the new building as designed, he might have a good cause of action for injunction.

Then there may be other cases where a building with ancient lights has been pulled down, but from one or other of many possible causes or from various causes combined no immediate or early rebuilding operations are commenced. In some such cases neighbours may be apparently justified in thinking that the ancient light rights have really been abandoned, and they may think themselves justified in building on their own land as though the ground on which the demolished building once stood were just a piece of ordinary vacant ground.

In some such cases there may be real grounds for doubt after some time whether the easement right is in existence or not, and the doubt can only be resolved by full and careful inquiry into all attendant circumstances which bear upon the question.

If it could be shown that the dominant owner had caused careful drawings or photographs of the old building to be prepared immediately or shortly before it was demolished, and marked the ancient lights on those drawings or photographs, or if there were other documentary evidence to show solicitude concerning the ancient lights, this kind of evidence might suffice to show that there was clearly no intention at the time of demolition to abandon the easement. Further, if there were any evidence of an intention at the time to erect new buildings with windows in positions corresponding to the ancient lights, there might be very satisfactory proof that there was a positive intention to preserve the privilege, and under such circumstances the privilege would survive ; but subsequent circumstances would have to be considered if there were any question of any subsequent abandonment. Speaking generally, the questions which arise in such cases are almost exclusively questions of fact to be tried and decided like any common jury case. The actual intention of the owner or occupier should commonly be inquired into when there is evidence of actual intention, but an intention to abandon may be presumed against him if he has acted in such manner as to induce the servient owner to believe that he would never resume the use and enjoyment of the easement, and more particularly if he were to stand by and allow a servient owner to expend a lot of money in building on an assumption that the easement was abandoned.

There are cases where, after a time, a man may be precluded from reasserting a right of easement unless he is reasonably vigilant and careful lest his conduct, considered in relation to that of his neighbour, may bring about a state of affairs where he may be estopped from setting up a claim.

It is here important to note that any question of abandonment can only arise after it is clearly established that an easement actually existed when the old building was pulled down.

Suppose, for example, that a building with windows which had been in existence for more than twenty years, but concerning which there had never been any suit or action, were pulled down, and suppose there had been no special privileges secured as easements by actual or implied grant, but that the owner had only his rights under the Prescription Act, then clearly, having only an inchoate right to an easement not yet complete, the demolition of the building would destroy the use, and after a year of non-use at latest the owner could not acquire an easement under the Prescription Act. It must not be forgotten by owners of household property that 50, 60, 70, or any other number of years of uninterrupted enjoyment of light through old windows will not alone suffice to create an easement, and that non-use or interruption, consented to or acquiesced in for one full year, will at any time suffice to destroy all claim for an easement under the Prescription Act.

When a house is pulled down the owner cannot use his old lights, and he may very soon lose all right to claim an easement for any new building which he may erect.

CHAPTER V

AIR

Although light and air are commonly coupled together in everyday language, when speaking of easements in connection with buildings it is necessary to distinguish between them, and to take note of some very important differences in the law applicable to each.

Air, like light, is one of the necessaries of life, and all people are entitled freely to use and enjoy it in a reasonable manner; but people may not use it so as illegally to injure others, nor may they illegally prevent other people from having such reasonable use and enjoyment of air as they may be entitled to.

It follows that there must be easements relating to air, but they differ from light easements as widely as air differs from light.

While light, with its attendant radiant heat, is motion, and has no mass or substance, but is a vivifying, stimulating, and purifying influence which travels mostly in straight lines, and can freely penetrate closed glazed windows, and is for the most part quenched in the uses to which it is put; air is a gaseous vaporous mixture of very composite constitution. It has substance, weight, and volume, and it moves bodily from place to place by gaseous diffusion or intermolecular expansion in all directions, and sometimes by flow in particular directions as air streams or currents. These air currents have not, as a rule, any sharply defined borders, unless they are enclosed in pipes or other channels bordered by walls. They do not ordinarily travel far in definite straight lines, as light does.

Also, air has not always the same composition. It can pick up and incorporate with itself by gaseous diffusion many gases and vapours injurious to life and health, and it can carry in suspension particles of dust and dirt, and the eggs or germs of large numbers of minute animal and vegetable organisms, many of which may be highly inimical to the health and life of man.

Also, air can only pass into or out of buildings through open apertures. The same windows which will admit light and air when open will admit only light and exclude air when closed, and a screen which may effectively stop the access of nearly all light to a window may not prevent the access of a plentiful supply of air.

The laws affecting the use and enjoyment of air must necessarily depend largely upon the natural physical and physiological properties of the substance concerned.

In former days, when less thought and attention was given to ventilation of buildings and to the effect of atmospheric surroundings upon the health than in these, there were comparatively few private disputes about air which came into the law courts for adjustment, and the total number of reported cases in which easement rights relating to air exclusively have been tried and decided is still very small by comparison with cases relating to light or light and air together. It seems probable that in proportion as people learn to set more and more value upon good ventilation and purity of atmosphere, disputes about air are likely to be more frequent than they have been in the past.

Easements in connection with air may have reference to access, exit, and route by which air should be allowed to travel, and they may also have reference to the purity or pollution of the air. Ordinarily all owners or occupiers have similar and equal rights as regards the uses they may make of their land or houses or other buildings, unless it so happens that special privileges have been acquired for, or by, the owners of particular tenements, by the exercise of which privileges the owners of neighbouring tenements may be lawfully compelled to put up with some restriction of their natural legal rights, or some injury or discomfort for the benefit of the dominant owner who is privileged.

The dominant owner is privileged to do something in excess of his ordinary natural rights, which affect his neighbours in the use and enjoyment of the natural rights appertaining to their tenements, such as they, in their turn, could rightly complain of or suppress as a trespass or a nuisance but for the existence of the privilege. In the case of Hall *v.* The Lichfield Brewery Company, decided in 1880, the plaintiff, who was a butcher, owned a slaughter-house with apertures for ventilation. There had been no material change in the structure of the slaughter-house, which had been used in its present form for more than thirty years before suit. Defendants built on their land so as to obstruct the free flow of air to and from the apertures. Plaintiff recovered damages for the obstruction on the ground of an implied covenant not to interrupt the free access of air suitable for the purpose of a slaughter-house.

In this and other cases relating to access or exit of air there have been definite apertures which have been more or less obstructed when the plaintiff has succeeded, but it has been held that in the case of a windmill there is no cause of action to restrain a neighbour from building on his land, although the building will inter-

fere with the free flow of air in a certain direction towards the sails of the mill. Similarly it has been held that building in such fashion as to interrupt a free flow of air towards a neighbour's chimney pots gives no cause of action, even when the owner of the chimneys is able to show that his chimneys smoke in consequence.

A very interesting case relating exclusively to air was that of Bass *v.* Gregory, where the plaintiff claimed to possess an easement right for passage of air through a defined channel, and to discharge foul air coming from his cellar into an old disused well in the yard of a neighbouring owner, who claimed a right to obstruct the orifice.

The chief facts of the case were these. Plaintiff owned a public-house, under which was a cellar, which was ventilated by a shaft cut therefrom through the solid rock, and terminating in an old well in a yard occupied by the defendant. The cellar was a very ancient one, excavated from the rock, and had been formerly used for brewing, for which use ventilation was necessary, and it was found, as a fact, that the ventilating shaft in question had existed certainly for more than forty years, and that there had been communication through that shaft to the well and up through the well and the grating at the top of it into the open air, so that the well became the ventilating shaft for the cellar. It was also found that this state of things was known to the defendant, and to those before him who occupied the yard in which the old well was.

The case was decided in favour of the plaintiff, on the presumption of a lost grant.

Concerning the degree of purity which a man may reasonably expect to find in the air which reaches his building, and the cases in which he may successfully take action against his neighbour for nuisance, or the cases in which a man may successfully assert and maintain a privilege by way of easement to pollute the air to an unusual extent, there is much room for conflict of opinion in different cases which may arise.

The right to purity of air, though a natural common law right, is from the nature of things one of degree only. No one has a right to demand that the air which reaches his tenement over the lands of others shall be absolutely pure. There is no such thing as absolutely pure air to be found anywhere in nature, and certainly not in inhabited regions, and no exact standard of purity can be prescribed concerning such a variable mixture as air, so that the natural right cannot extend beyond a right to air in a reasonably usable and enjoyable condition, and even when it is not in a wholesome condition for breathing or other uses, no man has a right of action against any other merely on that account, unless the person against whom the claim is made has been responsible for lowering its standard of purity or usefulness to an actionable extent. Speaking generally, every animal, dead or alive, and all vegetable matter detached from the earth, and all combustion, must tend continually to pollute or spoil the atmosphere in the neighbourhood, more particularly in regions where moisture abounds, so that all people living or working in the neighbourhood must suffer more or less from natural operations incidental to ordinary human and animal life and vegetable decay. All they have a right to demand is that the atmosphere shall not be polluted to an excessive or unnecessary extent by neighbours. They may object to anything which amounts to a nuisance. On the other hand, there are some trades and occupations which cannot be carried on without polluting the atmosphere to such an extent as to be a nuisance to neighbours.

In such cases an easement to pollute the air may sometimes be acquired by prescription under the old common law, though not under the Prescription Act, which is silent about air, and under which no easement of air can be obtained. An easement to pollute air may also be acquired by grant, but it is evident that unless the circumstances are very exceptional (such, for example, as when the original grantor owns all the land surrounding the tenement of the grantee for a considerable distance in all directions) a grant by one neighbouring owner will confer no rights as against any other neighbours or over their lands.

Hence actual or implied grants are not so frequently relied upon to establish an easement to pollute air as in cases where light and most other easements are in question. Prescription use and enjoyment under the old common law, with the old presumption of lost grants, will give a good title as against the whole surrounding neighbourhood, and this is the most usual means by which a privilege to carry on offensive trades may be gained.

It is so exceedingly difficult as to be practically impossible to lay down in explicit and exact terms how far and when an owner may pollute the air in his neighbourhood with impunity, and the exact circumstances under which a neighbour may be able to establish a cause of action, and to succeed in court, and to what extent and what remedies should be applied. To a very large extent the practice of offensive trades or manufacturers is a matter of general public interest, and in modern days dangerous and offensive trades are to a considerable extent brought under regulation and controlled by supervision in the public interest. Private owners of neighbouring property have, generally speaking, a right of action if there is a real nuisance of a character to cause depreciation of their property, and they may be able to obtain substantial relief in the shape of damages, and perhaps sometimes an injunction, if their own conduct in the matter has been reasonable, and if they have not acted in such a manner that acquiescence might be implied. The rights and conduct of all parties before the Court may be relevant to the inquiry, and to the remedies in these cases of nuisance, and even when a defendant carrying on an offensive trade is able to show a pre-

scriptive right of easement relating to the pollution of air as a necessary consequence of carrying on the trade or manufacture, it may still be a question whether the degree of pollution is more than is impliedly covered or protected by the easement.

There is this peculiarity about an easement to pollute air, that the easement secures to the dominant owner a right to pour offensive material into the atmosphere at large, and the dominant owner has no subsequent control over its distribution, nor any certain knowledge of the direction in which it may be carried, or how far, so that it is no easy matter to say which are servient tenements, and to what extent they are so. Also, the height at which effluvia are discharged into the atmosphere must in most cases materially affect the distribution.

Neighbours may therefore be concerned with structural alterations in factories and chimneys, and with changes in the processes which are carried on inside, so that in these days, when changes in processes and enlargement and alteration of factory bulidings are so numerous and progressive, disputes may easily arise where the main question will be whether the action of the factory owner is of a character to inflict unjustifiable injury on neighbouring property, and on the owners and occupiers.

The proportion of cases in which an easement can be successfullly pleaded by way of defence will probably be very small, and the rights and remedies of parties will for the most part be determined on the merits of each case.

It may here be noted that real injury to property, or real injury to health, actual or immediately threatened, must form the basis of complaint. Courts will not lightly interfere with the reasonable practice of any legitimate trade, except for good cause shown, and a fastidious taste or personal dislike of particular smells, which are not seriously unwholesome or dangerous to health, will not be accounted as giving a good cause of action against a neighbouring owner who acts reasonably and within his natural rights. For example, a householder may not like to have a butcher or fishmonger open a shop in his immediate neighbourhood, but if the business is carried on in a generally reasonable manner applicable to such shops, the dissatisfied neighbour will ordinarily have no cause of action for nuisance. On the other hand, if any man carries on a trade which is really a nuisance to neighbours, he cannot successfully plead, by way of defence, that the air in the neighbourhood was otherwise seriously polluted before he began to pollute it. The fact that other people are habitually committing nuisances in the neighbourhood does not justify the commission of a fresh nuisance by him if a neighbour objects. Also, a man carrying on an offensive trade or occupation cannot successfully defend an action for nuisance by merely pleading that the air was habitually polluted before the plaintiff came into the neighbourhood,—or in other words, that plaintiff has voluntarily come within range of the nuisance which would not otherwise have affected him. A man cannot merely, as first comer in a neighbourhood, originate a nuisance, and then insist that every new comer shall put up with its continuance. Each new comer will ordinarily be vested with a natural right to have unpolluted air to breathe and to use in other ways, and *prima facia* has good ground of action against anyone who seriously infringes that natural right; and the person causing the nuisance can only justify by proving an easement, unless there exists some special personal reason why plaintiff should not be allowed to assert his natural right.

Ordinarily, uninterrupted pollution for a full period of twenty years at least at the same place, in the same manner, and substantially to the same extent, will suffice to establish an easement if the practice has been continued all that time in a manner capable of being resisted, and if it has not been resisted. It may, however, be nearly always questioned how far and to what extent and when such easements can be held to be established.

CHAPTER VI

SUPPORT

The right of support is a natural right possessed by the owner or occupier of land that the surface level of his land shall not be disturbed by the removal of means of support either laterally or vertically, either adjacent or subjacent.

This natural right to support is absolute and unlimited, and without consent, actual or implied, the owner of land cannot be deprived of that right, and he has *primâ facie* a right of action against any one by whom the support to which his land is entitled is taken away; but the right is not infringed until such time as injury results from removal of support.

It is actual interference with the ordinary enjoyment of land which affords the ground of action, and not particular acts which may conduce towards the interruption of enjoyment. The owners of neighbouring tenements, when dealing with their own property, are *primâ facie* entitled to deal with it as they like, and they are under no legal obligation to leave or to substitute support in any particular form.

The obligation only extends either to the leaving sufficient natural support *in situ*, or to the substitution of other sufficient support in place of the whole or part removed, so as to prevent subsidence of a neighbouring tenement. Until that tenement is injuriously affected it cannot ordinarily be said that the amount of support left or substituted is insufficient. It may be observed that, whatever may be the nature of the soil, the ordinary obligation not to excavate or undermine or otherwise deal with the land of one tenement so as to cause subsidence of the land of a neighbouring tenement remains the same. If a man has a proprietary right to the minerals below the surface of his neighbour's land, and if he cannot find means to get at those minerals without causing the surface land to sink, he must leave the minerals where they are. If, on the other hand, the rocks are so hard and so arranged in the earth that he can take all the minerals away without interference with his neighbour's surface, he may do so. Between these extreme cases there are many others where the conditions are such as to admit of the gradual excavation of minerals or subjacent rocks, and the steady substitution of efficient artificial for natural support. Sometimes the support left is partly artificial and partly natural. It is sufficient if by one means or another, or by different means in association, the surface is adequately supported.

The same principles which apply to any kind of mining or burrowing beneath the surface of a neighbour's land apply to all cases of excavation or burrowing anywhere in the neighbourhood of land, which may possibly be caused to sink as a consequence. The person excavating should take efficient precautions to safeguard his neighbour's land from being made to subside as a result of the excavation, or he should abstain from excavation whenever there appears to be evident consequential danger to his neighbour's property. There is, however, one class of cases which form an exception to the general rule against removal of support. When land is heavily charged with water the surface may owe much of the natural support which keeps it in place to the water filling all interstices in the rocks below. For example, old mines may be filled with water, or spongy rocks may be saturated, and it is easily conceivable (as has, in fact, happened in some reported cases) that removal of the water by drainage may so weaken support as to cause subsidence at the surface. Nevertheless, neighbours cannot be held responsible for damage caused by removal of support as a consequence of the drainage of their land, nor for pumping large volumes of water from their own wells. The general rule would seem to be that, what a surface owner is *primâ facie* entitled to is such solid support as naturally exists under or around the margins of his land, which his neighbours, in the exercise of their several proprietary rights, must not diminish to such an extent in any place or any direction as to cause subsidence of the surface; or if they wish to do acts which will have the effect of weakening support to a dangerous extent, they must replace the support taken away by efficient substitutes.

A landowner is no doubt entitled to enjoy support from subjacent water while he has it, but he is not entitled to claim that neighbouring owners shall abstain from dealing as they please with water which they find on or under their lands, only because the quantity of water either on, in, or under his land may be diminished in consequence, and surface support thereby weakened.

There is, however, an apparent exception to the general exception in the matter of support by subjacent water. Although there is no general right to claim support of surface land by subjacent water, there is a right of water support for a surface canal or stream. Owners of land in the neighbourhood of a surface stream must not drain off the underground water if the effect is to lower the surface of the upper stream.

Evidently, if it were allowable to draw water under such conditions as to cause a subsidence in the level of a stream, while passing over the land of a neighbour, the effect would be equivalent to a tapping of the stream, and a part at least, if not the whole, of the water drained away might fairly be taken to be the stream water travelling by underground channels. Also in many cases, if such drainage were to be attempted, the underground currents of water, which would tend to become established would undermine the surface land, and carry away more or less considerable quantities of solid particles derived from subterraneous erosion, so that sooner or later solid support for the surface land would be so far weakened that the surface would fall in. The water rights of riparian owners of the stream might also be more or less seriously invaded or threatened if subterranean drainage of the kind indicated were to be practised.

Sometimes, when land is excavated, matter oozes or flows into the excavation, which is of such consistence and composition that it is by no means easy to decide whether it should rather be considered as wet earthy or rocky matter, or as water carrying mineral particles in suspension. As above stated, it is *primâ facie* quite lawful for an owner of land to drain stagnant water from his own land, whether at the surface or below it, and he may sink wells and use pumps to fetch up the water; and if his neighbour's land suffers from removal of water support by such means he is not liable for the injury inflicted. There may easily arise cases from time to time where so much solid material, mixed with, or suspended or dissolved in water, will be displaced from beneath one tenement and carried away towards excavations in a neighbouring tenement, that surface damage may result for which the person excavating might be held legally responsible.

The questions for decision in such cases are for the most part questions of fact, but they may be facts of such an uncertain character that it may be very difficult, indeed, to arrive at a final and just conclusion concerning them.

A right to adjacent support must not be taken to be limited to land immediately adjacent so as to exclude the liability of owners of more distant tenements, when excavations on those distant tenements can be proved to have caused the injury complained of. Theoretically, there is no limit of distance, and the existence of intermediate tenements is no bar to a claim for damages for removal of support if the facts are such that the damage inflicted has clearly resulted from acts done by a distant owner or occupier upon his land. In some cases excavation may really cause injury at a distance, while in other cases excavation, such as quarrying solid rock, for example, may be carried on quite close up to the limits of a neighbour's land without danger of inflicting injury within his borders.

When actual subsidence of a surface has taken place, and it is alleged by the owner to be due to the acts of a neighbour who has removed support to an actionable extent, it may sometimes be shown that the owner of the damaged tenement has weakened his surface by excavating on his own land; and if it should appear that he has contributed towards the effect finally produced by this or other means, the neighbour will not be responsible merely because he also has contributed to diminish the support, and thus ultimately caused the subsidence. In such cases the owner complaining of injury must show not merely that neighbouring excavations have caused the subsidence on his land, but that they would any way have produced the same result if his land had been in its original natural condition; or else it must appear that he has acquired an easement right, binding upon his neighbour as a servient owner, to leave an additional amount of support sufficient to counterpoise or compensate for the increased weakness of his surface. Otherwise the neighbour will not be held legally responsible for the damage, because in excavating on his own land he is *primâ facie* acting within his own natural rights, which are only limited by, and coterminous with, the natural right of his neighbour for support sufficient for his land in its natural unweakened condition.

The same principle applies where heavy buildings have been erected upon land. Neighbours are not *primâ facie* liable to provide any extra support for the buildings, nor are they bound to abstain from excavating or otherwise dealing with their lands as they might have done before the buildings were erected.

Their rights are the same after as before the erection of the buildings, and are limited to a legal obligation to leave sufficient support for the land, such as it was before the buildings were placed upon it. The person who has erected the heavy buildings could not place increased burthens, or impose increased restraint on neighbouring owners or occupiers without their consent; neither could the neighbours repudiate or otherwise get rid of their obligation to respect the natural right of support for the land built over.

A right to additional support for houses could only be acquired as an easement by one or other of the means by which such easements can be brought into existence. Until an easement has been acquired there is no obligation for any neighbour to contribute in any way towards the support of the house apart from the land it stands on, which is entitled by natural right to have sufficient support for itself alone, as if it were still unweighted.

When, therefore, a house suffers damage as a consequence of removal of support by a neighbouring owner or occupier, it is important to know or ascertain in each case whether an easement of support exists which is binding upon that neighbour as servient occupier of a servient tenement. If such easement exists, and the house is damaged as a consequence of illegal removal of support by a servient owner, that person is liable for the damage; but if no easement

were in existence the neighbour removing support would not ordinarily be responsible unless he had failed to leave sufficient support for the land in its original vacant condition.

Sometimes buildings are supported (in part at least) by other buildings, and rights of easement for such support may be acquired; but in the absence of an easement the owner of a building is not ordinarily under obligation to afford continued lateral support for buildings close to his own. He is not under any legal obligation to consult his next-door neighbours before pulling down his house, nor to shore up the walls of adjacent houses when he pulls down his; but he must, of course, take care that in pulling down his house he does not damage the property of his neighbour.

This obligation, binding upon every man to take care that he does not injure his neighbour while looking after his own interests (*sic utere tuo ut alienum non lædas*), is of particular application to the case of closely adjacent houses, where, by want of care in effecting structural alterations, more or less serious injury might be easily inflicted upon neighbours and their property; but neighbourly consideration and the special carefulness which special circumstances may require are matters apart from the law of easements. The owner who wishes to pull down his house, where no easement of lateral support for a neighbour's house exists, is not under obligation to abstain from the exercise of any or all his natural rights arising out of the ownership of his house. He is only bound to be careful as to the way in which he exercises his rights.

Although the extent of the natural right of support for land from a neighbouring tenement is not affected immediately either by excavations upon the land or by buildings erected on it, or by the excavations of others on adjoining land, yet after the lapse of a sufficient time easements may be acquired for the support of the land in its altered condition, and for buildings on it.

Besides the easements for special support in excess of the original natural right, an easement of the opposite kind is sometimes created which gives to the dominant owner a right to take away support in excess of his natural right, so as to leave surface land unsupported. This kind of easement is not uncommon in some mining districts, where owners of minerals would be seriously restrained in the exercise of their natural right to remove coal and some other minerals if they were under continual obligation to maintain adequate support for the surface.

Any of these easements may be acquired by grant, express or implied.

It is not necessary here to discuss express grants. Such grants to create or transfer easements must be by deed, and the deed should sufficiently indicate and describe what is granted or what is reserved by covenant.

A more common means by which easements of support, like many other easements, are acquired, is by implication when real property is transferred.

When an owner of land with buildings sells any of the buildings, either with or without the land on which they stand, there is an implied grant of support for the buildings sold, which is binding upon the lands of the vendor and any other person deriving title from him. The vendor has, of course, no power to bind or impose burthens on lands or buildings other than his own, so that if he sells a new building recently erected near the margin of his land, the easement thus created by implied grant at the time of sale may protect the building against removal of support subjacent and adjacent on one side, while an owner of land on the opposite side may remain free to excavate his land at short distance from the building so as to jeopardise its safety without being liable for any consequent injury to the building.

The same principle of grant by implication arises when an owner of several adjacent houses sells the houses separately to different purchasers. If the houses have been in any way dependent upon each other for lateral support they will be affected with easement rights and obligations after the purchase and sale, the owner of each house being servient to his adjoining neighbour for lateral support. The rights and obligations thus created will be reciprocal. The owners of the houses must not in such cases excavate to such an extent or in such manner as to endanger the stability of the houses adjoining, and will be liable for any injury which may be caused to the adjacent neighbours as a consequence of such weakening of support by excavation or any other means. When land is granted for building purposes an easement right for support of the buildings after erection is impliedly granted. The easement for support of buildings may spring into existence directly the land is sold for building purposes. The vendor must not so weaken support for the land sold that buildings such as were contemplated at the time of sale could not be safely erected on the land sold, any more than the vendor could be allowed to jeopardise the safety of the buildings after erection by taking away the requisite support.

The general rules applicable to all ordinary cases where an owner of land sells part of it may perhaps be safely formulated thus. Whenever an owner sells part of his land or buildings there is an implied grant (binding upon him and his successors in title to whatever part is reserved) of such extent of easement right as is necessary to give full effect to the grant and secure full enjoyment for the grantee of what is intended to be bought and sold.

If an owner sells land for ordinary agricultural purposes, reserving right to minerals below the surface, the vendee takes the land subject to natural rights of support for the surface in the state in which it exists at the time of purchase, together with right of support for any buildings which may have been on the surface at the time of purchase.

New heavy buildings he can only erect on the land at his own risk, unless he makes prior arrangements with the owner of the subjacent minerals. Otherwise he may not only incur the risk of injury to his house, but may also be liable for injury to subjacent mines and minerals.

If a man sells houses, he must be taken to grant impliedly all manifest easements relating to the houses sold, and he can have no right subsequently to deprive those houses of support unless he has preserved such right by express reservation at the time of sale, or acquired it by regrant or other legal means after the sale.

When the owner of land sells the minerals and reserves for himself the surface, then (on general principles, and in the absence of any express covenants relating to the matter) the grantee of the minerals will be *primâ facie* entitled to take them all away without being under obligation to support the surface.

When surface and mineral rights are severed by Act of Parliament, or by other means than voluntary grant, presumption based on the theory of implied grants would ordinarily be excluded, and separate owners would be left in the enjoyment of their natural rights, except so far as they might be altered by Act of Parliament. Railway companies, for example, are made subject by Acts of Parliament to special laws enacted in their behalf, and in behalf of those persons whose lands have been acquired by the companies for the purpose of making railways.

Ordinarily railway companies acquire by purchase surface land only, and not underlying minerals; but when the removal of minerals from below a railway line might be likely to cause injury to the surface the company, under terms and conditions specified in the Lands and Railway Clauses Consolidation Acts of 1845, may cause the working of the mines to be stopped and compensate the owner of the minerals for all loss.

The question whether railway companies are entitled to support like other surface owners has been raised and fully argued in the House of Lords, and it has been decided that a railway company, under a statutory purchase of the surface land which does not include the subjacent minerals, cannot "claim the benefit of the right of an ordinary purchaser of the surface to subjacent and adjacent support, the statute having created a special law for such matters, by which alone the rights of the company and mine owners are regulated."

Special rights to excavate may also be acquired under Inclosure Acts.

Often rights of support in excess of the ordinary natural right for the support of surface are acquired for houses without any grant either express or implied. A right of support for a house may accrue from the mere fact that it has stood where it is for a long time (twenty years or more) and support has been enjoyed during that time.

This was decided by the House of Lords in that most remarkable case, Dalton *v.* Angus, reported in Appeal Cases, vol. vi. pages 740 to 852.

A perusal of the judgments and judicial opinions delivered in that case (which was very fully argued at different times before no less than eighteen judges, including the Lord Chancellor and four other Law Lords, three Lords Justices and the Lord Chief Justice and nine other Judges of the High Court), whose judgments and opinions fill altogether more than 180 pages of the Law Reports, should suffice to convince anybody of the excessive difficulty and complexity of the theory of the law relating to rights of support.

Since the final decision of that case there can no longer be any question that a right of support for buildings by land may be acquired by enjoyment for twenty years, although the theoretical foundations on which that right is built are still very obscure.

A few months after the final decision of the House of Lords in Angus *v.* Dalton it was decided by Hall, V.C., in Lemaistre *v.* Davis, that the principle of Angus *v.* Dalton applies also to lateral support of building by building. Twenty years of enjoyment creates a right to continued support. Before Angus *v.* Dalton was finally decided there had been some decisions exactly the other way.

It will be understood that all rights of support, whether they be simple natural rights or easement rights created by express or implied grant, or easements acquired by long enjoyment, are liable to be affected by private agreements or by Acts of Parliament.

Concerning rights of action and remedies for removal of support, a distinction must be made between the cases of neighbouring owners or occupiers who are *primâ facie* acting within their rights in excavating their own land, and trespassers or wrong-doers who have no *primâ facie* right to excavate.

These latter will ordinarily be liable for any damage caused by removal of support to a building, whether the owner had acquired an easement or not. The rightful owner or occupier is not liable for damage resulting from the exercise of his natural proprietary rights, unless he has exceeded his right by invading the rights of his neighbour. A wrong-doer, or a man acting without a *bona fide* claim of right derived from ownership, is liable any way for the damage he may do. The mere fact that a house is standing is enough to give a good title as against any one except the owner of neighbouring land or buildings or persons claiming under him.

In the early part of this chapter it has been pointed out that it is damage resulting from removal of support which gives a cause of action. Limitation begins to run from the date of damage, not from the date of removal of support,—indeed, it must in the nature of things be very difficult, if not impossible, for the person injured to know or ascertain in many cases what

exactly is being done by neighbours which may weaken his support, and the possible effects and consequences cannot be clearly foreseen, so that when damage does actually occur, and only then, is it apparent that, for some reason or other, support was not sufficient.

The person complaining must be able to show the damage—to prove that it is due to removal of support by defendant—and to prove that his land and buildings were legally entitled to support at the time the damage was done. He must also be able to negative any counter explanation put forward to show that he has contributed to the result by his own acts, or the acts of others under his control, or that there have been some other or perhaps natural causes for what has happened.

Among the many possible causes which might account for damage might be bad building, structural defects, old age, increased weights introduced into the building, heavy or leaky roofs, bad drainage, and many other things which might have been done in and around the house by the occupier or others.

A man who has been apparently exercising his own proprietary rights on his own land in a reasonable manner for *prima facie* legitimate purposes, and in furtherance of what he may believe to be the best interests of his estate, cannot be easly held responsible for damage to buildings on a neighbouring estate.

The damage, the acts, the relation between them, the obligation to support, and the absence of other or contributing causes, may all come in issue, and the difficulties in the way of establishing a good case against a neighbour for damages for removal of support may often be very great, as indeed it is evident that they should be.

Everyone who wishes to build should as far as possible make adequate arrangements of every kind for the secure support of the buildings to be erected, and depend as little as possible upon the owners of neighbouring tenements.

From the fact that it is the damage consequent on acts done which gives a cause of action, it follows that each new damage gives a new cause of action, even when there have been no new acts to cause the extra damage.

It may readily be understood that when the foundations of a house have suffered injury by subsidence or fracture, or both, from want of sufficient support, the consequent damage to upper visible parts of the building may be progressive, either gradually or by fits and starts, and it may be difficult or impossible to foretell with any reasonable degree of certainty how far the damage may ultimately go. The liability ends only when the damage ends, but the damage must be traceable to the cause.

PART III

HEATING, VENTILATING, AND LIGHTING

CHAPTER I

THE PRINCIPLES OF HOT-WATER APPARATUS

(Anonymously Contributed)

For a correct understanding of the working principle of any form of hot-water apparatus, whether for domestic supply or for warming buildings, it is essential that the cause and action of the circulatory movement of heated water be described and understood. The want of this knowledge is chiefly accountable for the many failures experienced in this work, the average hot-water fitter being, as yet, but little better than a copyist—able to repeat previous successes, but often failing when the work entails a departure from ordinary undertakings.

The circulatory movement that occurs in water when it is heated, on which the hot-water engineer relies, is due to the action of *Convection*. To describe this action, it has first to be explained that water, mobile as it is, consists of a mass of separate particles—molecules as they are termed, each particle being independent of the other and having the property of mobility in a very pronounced degree. The mobility of the particles, as the term implies, admits of their gliding over, under and around one another in a manner that indicates an entire absence of friction or resistance, some authorities going so far as to say that there is a separating or repelling force existing, causing the molecules to work free from one another instead of rubbing. The physical condition of water, therefore, is that of a mass of extremely minute particles in a state that admits of their moving freely in any natural direction when quite a trifling force is brought into play. It will be seen directly that a motive power of exceeding weakness will set the molecules of water moving with astonishing rapidity.

A very simple experiment will illustrate convection currents, it only being necessary to suspend a glass jar, filled with water, over some simple source of heat, such as a small benzoline or spirit lamp, or over the chimney of a small paraffin lamp. It will be found, however, that water is invisible—certainly the action of convection is; but this difficulty can be overcome by using a solid visible substance in the water, which will indicate whatever movements may be occurring. Doubtless the best material to use is amber in a powdered form, this having a specific gravity very nearly the same as water, and it will consequently remain suspended in it, stationary when the water is still, and moving in accordance with any motion of the water. A piece of broken pipe stem, easily obtained where pipes are repaired, will serve, if a part of it is filed into powder. There may be disappointment due to there being so many clever imitations of amber, but a piece of true material is not difficult to obtain, and this is worth doing if experiments in hot-water circulation are to be undertaken.

The amber dust is put into a bottle with some water, the two being well shaken together. After allowing the bottle to rest for a little time, it will be found that some of the dust has risen to the top as a scum (which can be removed) while some has sunk to the bottom. There will, however, be a good quantity suspended in the body of the water, and this is the part that should be decanted off for use. On making an experiment it will be found that the movements of the amber particles are quite visible, and they correctly represent the movements due to convection currents. A rather full explanation is devoted to this owing to the great advantages obtained by being able to observe—*to see*—what is occurring with the water.

The cause of the circulatory movements is explained as follows. When the water in a vessel is cold—the particles being of uniform temperature—the whole mass will be found to be stationary. On applying heat to the bottom of the vessel the particles nearest

that point become warmed, and, like almost everything in nature, they expand, becoming larger than their colder fellows. An increase in bulk of each warmed particle occurs, but there is no increase in weight. It is common knowledge that any substance which is lighter, bulk for bulk, than water, cannot remain at the bottom of a vessel of water. It, instead, immediately rises to the top. The rise is not directly due to the lighter quality of the substance, for if a piece of cork, or a hollow rubber ball, be placed on a table it shows no inclination to rise, but if either be placed at the bottom of a vessel of water it will ascend to the top at once.

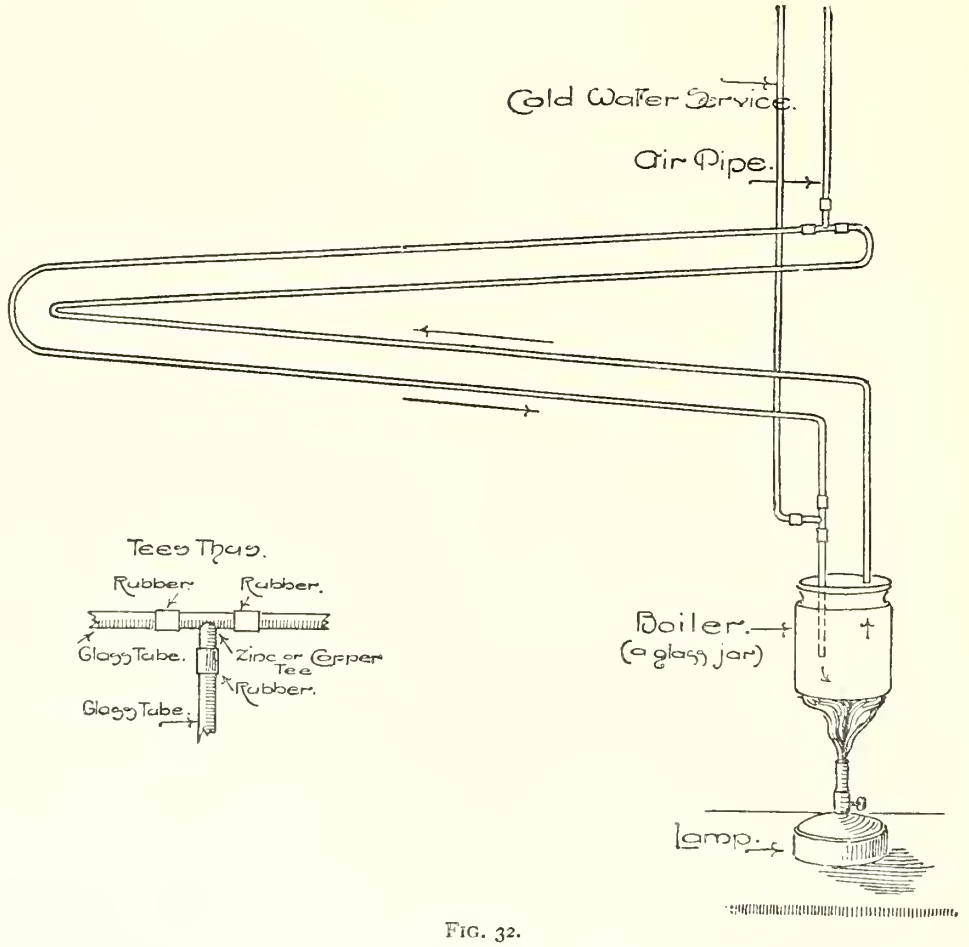


FIG. 32.

The upward movement of the warmed molecules of water is due to the greater weight of the cooler particles, these latter sinking beneath their lightened fellows and literally lifting them up, just as they would lift up the cork or ball. This action should be realised and remembered, for many persons occupied in heating works still retain the idea that heated water rises because it is its nature to do so. It is said that hot water always rises, as if it would of its own accord flow over the edge of a vessel; whereas water, whatever its heat, has its particles stationary if they are all of the same temperature. It is only when the particles are given an increase in bulk, and so made lighter for a given size than their fellows, that movement occurs.

There are several instructive and distinctly interesting results to be noted from even so simple a contrivance as that just explained. There will be seen, for instance, what has been termed the "skin" of water; for however freely the main body of water may be circulating, a thin surface at the top remains quite still and unaffected. It can be seen, too, how an upward movement occurs in the centre with a downward current around all sides, if the lamp is placed centrally; while the up-current can be confined to one side and the descending movement to the other by putting the lamp nearer one side than the other. It can also be seen how easily the circulation can be reversed by shifting the lamp from side to side. Finally, the theoretical explanation just given can be proved by letting the contents of the jar be first heated, and then, after the lamp is removed and the water has become stationary, the circulating movement can be started by placing a cold object in or on the top of the water. In this case the warmed particles are cooled, contracted, and made heavier (bulk for bulk), and the circulation is then more plainly due to the superior weight of the coolest particles.

The foregoing, it will be noted, refers wholly to the

circulation of heated water in a vessel, a thing worth studying in the way described, remembering the small trouble and expense involved. For practical hot-water work, however, the vessel, representing a boiler, must have pipes extending from it, and the circulatory movement must not only occur freely through these pipes, but the movement must take place up one pipe and down the other, and not both up and down in each.

It is not a very easy thing to explain why the up and down movements occur separately in the two pipes, in the very positive and reliable way they do. When the pipes are attached to a boiler they are connected one at top and one at a low point (as is fully explained later), and the common explanation is that this fact accounts for the phenomenon just referred to. It is not so, however, for if, for experimental purposes, both pipes are connected quite level with one another at the top of a boiler, the circulation, up one pipe and down the other, occurs just as freely and starts as instantly as usual, without hesitation.

It is to be strongly recommended that a simple apparatus, constructed of glass, be made and experimented with by all interested in this work; and for initial investigation an easily erected and inexpensive model, such as is shown in Fig. 32, will serve to settle many points. That an effective circulation can be obtained with the pipes both connected at the same level at top can be tried by arranging them as shown in Fig. 33. It will be found, as stated, that the circulation will set in promptly, but there will be no certainty as to which pipe will have the up-current and which the down. This will largely depend on whether the lamp is more under one pipe than the other. The object, therefore, in making boiler connections, one high and one low, is not to produce the requisite circulation, but to ensure its always occurring in one desired direction. With the connections at the high and low points there is always a certainty as to which pipe will be the "flow" and which the "return." The flow-pipe is that which has the ascending, while the return-pipe has the descending current in it.

The small model illustrated in Fig. 32 consists of a glass jar of 2 to 3 inches diameter, having a large neck aperture. It is closed by a tightly fitting cork, which can be waxed over with sealing wax if desired. Two holes are bored in the cork for the pipes to fit tightly into. The pipe is glass tube of about $\frac{5}{16}$ or $\frac{3}{8}$ inch size, costing about one penny per yard, and this can be easily bent in any gas flame — a bunsen flame for preference, as it does not discolour the tube. The tees can be of copper or zinc tube, soldered up. The joints are made with short pieces of flexible rubber tube (such as can be obtained from a chemist) of rather smaller size and stretched on. Amongst several points to be observed with this model is the rapidity with which the circulation sets in, it commencing almost instantly the lamp is put under, which,

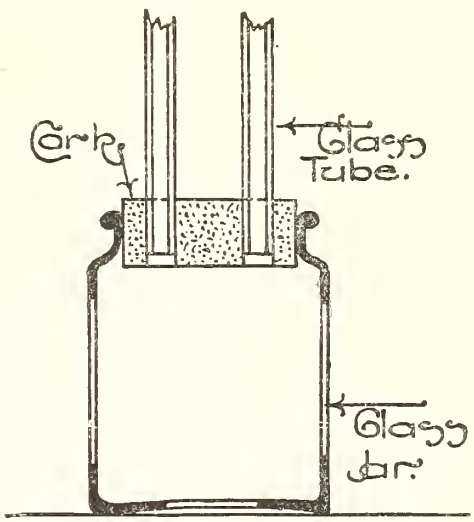


Fig. 33.

remembering the low conductive power of rather thick glass, goes to show that an extremely small rise in temperature will set the water in motion. It will also be seen that, instead of the circulation being local to the boiler for a little time, as is commonly supposed, it commences at once both in boiler and pipes. Experiment can also be made as to the effects of putting the air pipe in the wrong place, or of omitting it, or of grading the pipes wrongly, etc. Needless to say, a much more extended apparatus can be erected about as easily as this simple one, and much, very much, can be learned, while the solution of problems is made moderately easy.

CHAPTER II

DOMESTIC HOT-WATER SUPPLY—GENERAL PRINCIPLES

Before describing the different designs or "systems" of apparatus erected for furnishing a supply of hot water at baths and other taps, it is necessary to point out and discuss one particular feature, the consideration of which is greatly neglected; yet it is the one essential feature of an apparatus expressly designed to yield hot water at taps. The average fitter devotes all his thoughts to obtaining a circulation, apparently not realising that this is the easiest thing to get, if certain simple rules are observed; whereas greater care is needed in proportioning the apparatus to the expected demand for hot water; and, most importantly, designing its details to ensure that the hot water, little or much, can all be withdrawn from the taps—any tap—without cold water being mixed with it. These works are always erected in such a manner that, on withdrawing hot water from a tap, there is a simultaneous inflow of cold water into the apparatus to make good the loss, and skill is needed to make the connections so that, as the cold water enters, it pushes, so to speak, the hot water before it, and does not mix freely. The outflow of hot water and inflow of cold are very closely related actions, for one depends on the other. When a hot tap is opened it is literally correct to say that the cold water immediately seeks to reach that tap; therefore the engineer must arrange that if cold water does issue from a hot tap there must be a positive feeling or knowledge that all the hot water has issued before it. In some works, quite a number in fact, the inflowing cold water not only mingles with the hot, but sometimes reaches and flows from a tap when the application of the hand plainly shows that there still remains hot water in the tank of the apparatus. This is a bad result very easy of attainment, if the subject is not properly studied.

To investigate the movements that occur in a domestic hot-water apparatus when a tap is opened, a glass model should be employed, and fortunately this is almost as easy to prepare as those illustrated in Figs. 32 and 33. Let it be clearly understood that the actions and movements occasioned by an open tap are totally different, and brought about by quite different causes, from those of the circulation, which is due to convection. There is no relationship whatever, but fortunately one very rarely interferes with the other except at the moment of occurrence. It is quite peculiar to see, in a model, first the swift but very smooth movement of the circulation, then,

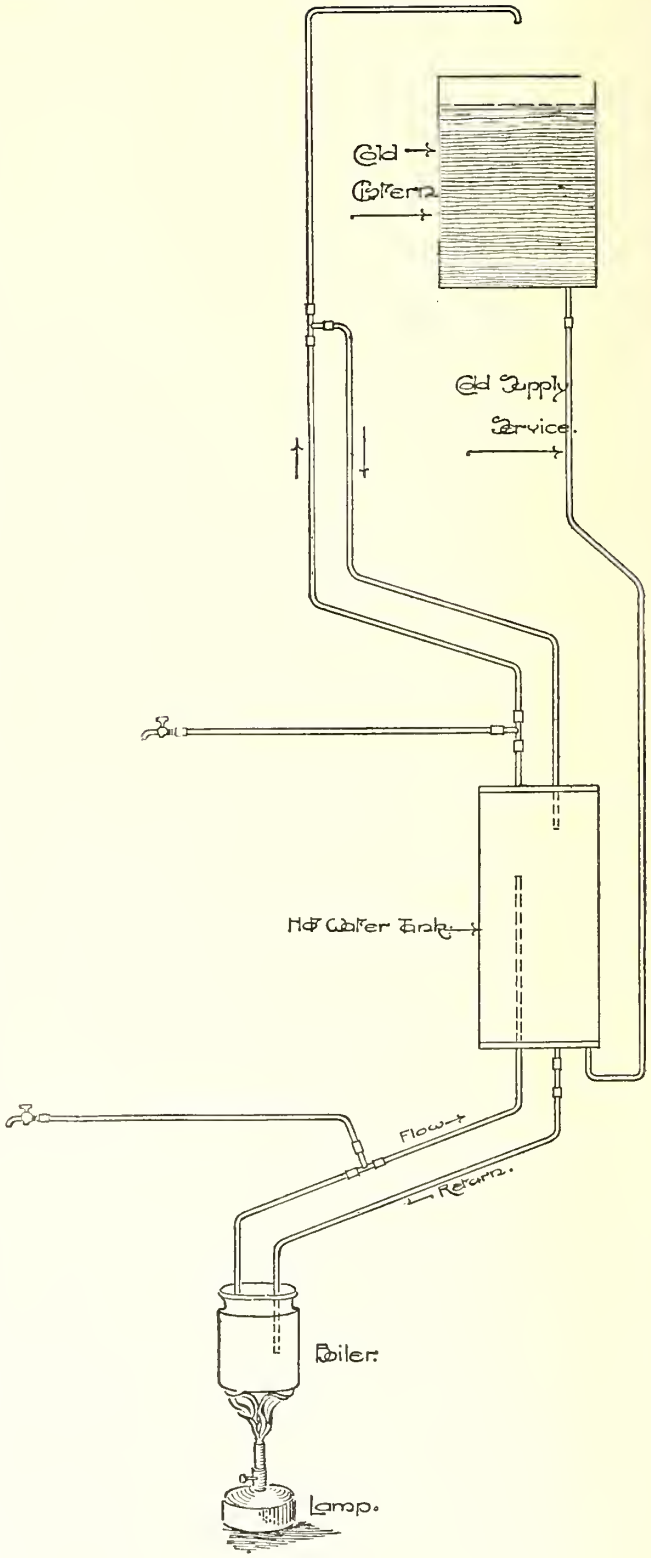


Fig. 34.

on opening a tap, a violent rushing of water, usually in quite a different direction, and finally the resumption of the circulation, without an instant's hesitation, immediately the tap is closed.

Fig. 34 illustrates a model that may be constructed for this purpose. The boiler, pipes, joints, and source of heat are provided in the manner described in connection with Fig. 32, while for the central hot-water reservoir a lamp chimney, short but of good diameter, is used, the ends being closed with corks, waxed over with sealing wax if necessary. The cold-water cistern need not be of glass—a preserve tin will do.

In this model it will be seen that there is a pair of pipes both above and below the hot-water tank. In this respect the apparatus resembles what is known as the cylinder system in its best form, but the idea of providing the two sets of pipes—a circulation below and above the tank, and bearing the trade names of the primary and secondary circulations—is to enable the student to experiment with and learn practically all the actions that occur in an apparatus whatever its system or kind. The two draw-off branches, one below and one above, are provided with this end in view. The cold supply service, unlike that in an apparatus intended for warming buildings, is best not connected into a return pipe. It is customary to let it enter the bottom of the hot-water tank, and in an apparatus erected in a house there is an elbow or tee put on the cold-supply connection, inside the tank, to prevent the inflowing cold water "boring up" through the bulk of hot water above. This undesirable action can be tested in the model. The taps, it may be explained, can be pipe-light cocks with their noses notched underneath and then bent down.

CHAPTER III

DOMESTIC HOT-WATER APPARATUS—THE TANK SYSTEM

The oldest form of apparatus we have for domestic hot-water supply is that known as the Tank System, and on this account it is commonly condemned as being out of date. Engineers who practise this work largely, however, quite frequently adopt this system when the conditions make it appear desirable to do so, and its erection does not by any means indicate ignorance of the work or of the latest ideas. The chief fault found with it is that, the tank being above the tap branches, it becomes possible to empty the apparatus should a shortage of water occur, and then a certain element of danger may appear. There is little to fear, however, in places well served from a Water Company's mains, but in country houses having the water supply dependent on a man's attention at a pump the tank system is well avoided. The more modern *Cylinder System* has not this fault, but it has another which the tank system does not possess, which will be explained later. A still more modern apparatus, called the *Combined Cylinder-Tank System*, has the advantages of both and the faults of neither, though it costs a little more.

It may be said that the names of these appliances are derived from the hot-water reservoirs—those which are square or rectangular being called Tanks, while the others are of cylindrical form and are called Cylinders.

In Fig. 35 are given the customary details of an apparatus on the *Tank System*. At the base of the apparatus is the boiler, to which the flow-pipe is connected at the extreme top, while the return terminates at a lower point. The reason for this difference in levels of the ends of the two pipes is to ensure the circulation always occurring in one desired direction, up the flow and down the return. The flow-pipe should always enter the top plate of the boiler, as shown, and it is important that it shall not project through inside the boiler in the least degree. The $\frac{3}{8}$-inch plate of the boiler is not a very thick substance in which to screw a pipe soundly without the pipe projecting through on the other side of the plate, but this difficulty is got over by the use of a back-nut, as shown in Fig. 36 (the return pipe is not shown). The fault that arises with a flow-pipe which is screwed through the plate, so as to project inside, is shown by Fig. 37. It will be seen that the boiler does not fill with water, there having necessarily to be some air imprisoned in the top when the apparatus is charged. Fitters have been known to remedy this by loosening the manlid, after the apparatus is charged, sufficiently to let the confined air be driven out, after which the lid would be tightened and the difficulty

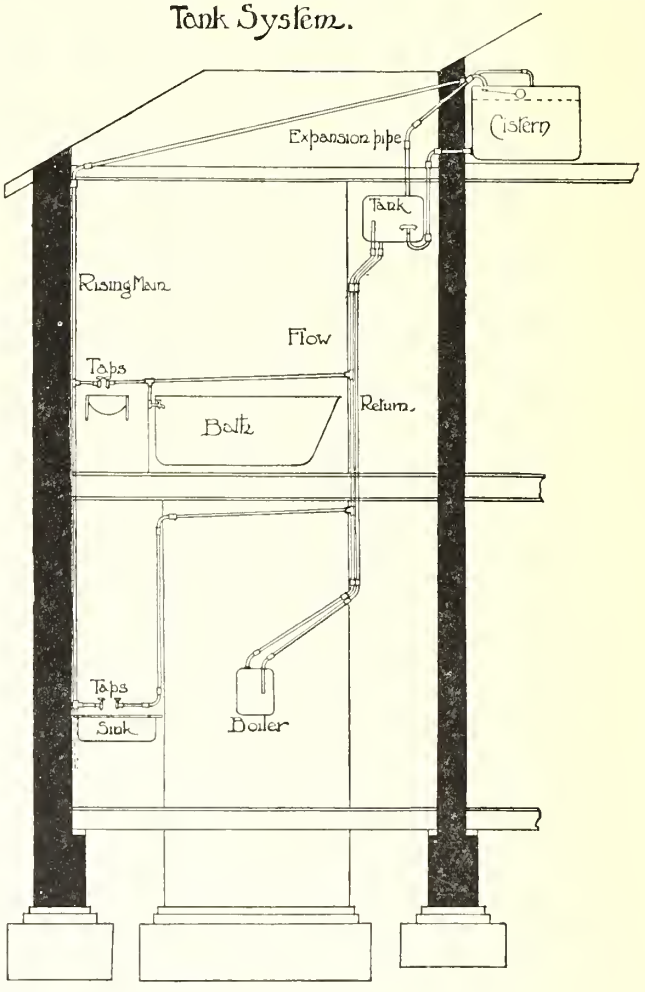


Fig. 35.

assumed to be ended. There remains the fact, though, that every fresh volume of water when it is heated discharges or releases a certain amount of air, and consequently the air collection at the top of a boiler, connected as in Fig. 37, may be considered as practically permanent. The confined air does not interfere with the circulation to a noticeable extent, but is a

prolific cause of noises, which are quite alarming when a good fire is burning and the water very hot.

The return pipe is commonly connected through the top of the boiler, as in Fig. 38, the short internal dip-pipe reaching a little more than half the way down the boiler, as shown. (The flow connection does not

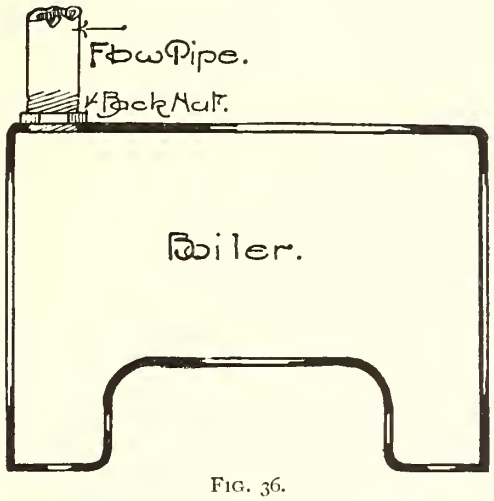


Fig. 36.

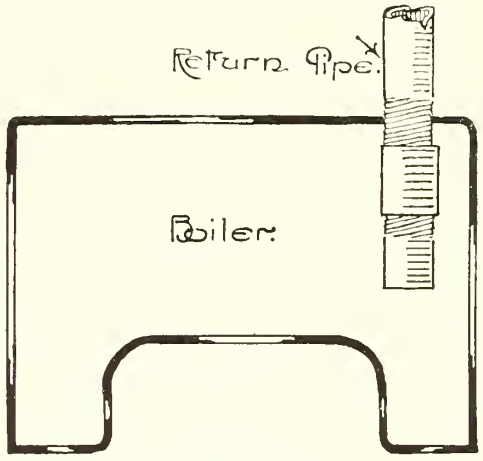


Fig. 38.

appear.) Whenever preferred, the return may be connected to the side of the boiler, either with a bend as in Fig. 39, or coming horizontally through the chimney jamb.

From the boiler the two pipes may take any convenient course to reach the tank, but at all points they

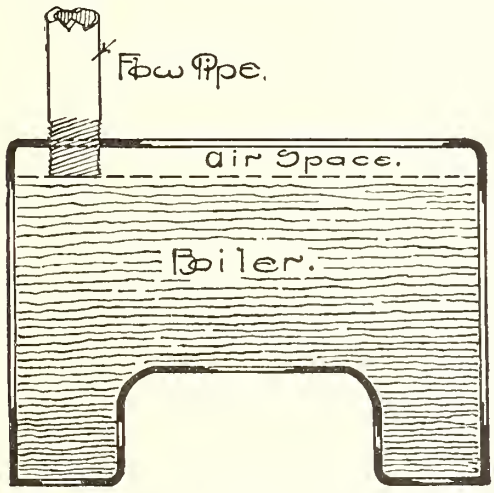


Fig. 37.

must be made to ascend little or much and not descend or even be quite horizontal anywhere. The least rise given to these pipes is 1 inch in 10 feet, and although horizontal pipes may be spoken of, and may be referred to in this book, *the pipes should never be quite horizontal*, even for a short distance. The purpose of the rise is not to cause or even favour the circulation, so far as inducing the circulatory movement is concerned. The idea that a rising pipe is essential to the action of convection is very widespread, but a brief investigation with a model apparatus will show that, provided the total height which the pipes extend to remains the same, it makes little difference whether the horizontal lengths be quite flat or are given the proper rise. The necessity of giving the rise lies in the fact that provision must be made for the unimpeded escape of air from all parts—air which is being constantly released from the water in this description of apparatus. It is not to be inferred that the circulation will be a success if the pipes do not ascend from the boiler at all, but that the customary rise given to hot-water pipes, where they have to run in a horizontal direction, is a necessary one to admit of air getting away, and this only.

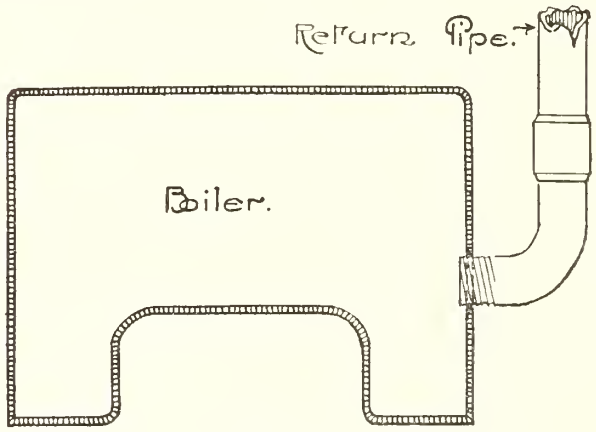


Fig. 39.

At their upper extremities the pipes enter the hot-water tank, and here again they end at two different levels, though for a totally different purpose to that aimed at in the boiler. In this case also an erroneous idea prevails, that by ending the pipes at different levels some advantage, or essential help, is afforded to the circulation; but it will be found that nothing of the kind occurs, the circulation being all that could be desired,

always, with the pipes ending level. Had the circulation only to be considered, the pipes would best be both at the bottom of the tank, but in order to obtain hot water at a tap the pipe drawn from must not come from a point where the coldest water is. The bottom part of the tank nearly always contains cold—at any rate, the coolest water, and immediately any tap is opened there is a simultaneous entry of cold water to the bottom of the tank; therefore the engineer must terminate his flow-pipe away from here and end it where the hottest water is, and where it can all be drawn from, little or much, without cold water mingling with it. On this account the flow-pipe terminates at a high point in the tank, delivering its hot water there as it ascends from the boiler, and drawing the hottest water from there when a tap makes a demand on it.

The next important detail is the cold supply service, which feeds the apparatus with cold water as fast as any warm water is withdrawn. This is the pipe shown coming from the house cistern to the tank, entering it at the bottom. There are no valves in the pipe (unless a stop cock be inserted to shut off the water when repairs or boiler cleaning are to be undertaken), so that there is open connection between the cistern and tank. It will be noticed (see Fig. 35) that the pipe first descends a little below the tank and then rises up to the bottom. This is done intentionally, to obtain a dip—miscalled a siphon—to prevent heated water working back up the pipe into the cold cistern. Hot water will travel, circulate in fact, up a single pipe, but by starting the pipe in a downward direction (where it leaves the source of hot water) this fault is quite avoided. A 6-inch dip is sufficient for this purpose.

On the cold supply connection, and inside the tank, a tee-peice will be observed. The purpose of this is to prevent the inflowing cold water "boring" its way up into the stratum of heated water above. The tee causes the delivery to be in a horizontal direction. An elbow answers the purpose just as well. Occasionally a fitter will make his connection as shown in Fig. 40, this giving a horizontal delivery, but probably the best method is as in Fig. 41, though it is seldom practised. As will be understood, the idea is to deliver the cold water in such a manner as will keep it as a level stratum in the lower part of the tank, not disturbing nor mingling with the heated water above.

From the top of the tank there extends a tube, known as the expansion pipe (see Fig. 35). Water expands to a known degree when heated, and in an apparatus of this kind the greatest amount of expansion is probably about 1 in 28); that is, 28 gallons of cold water occupy the space of 29 gallons when very hot. The expansion pipe does not accommodate this extra water, however,—for it would have to be a very large pipe to do so in some cases,—but it admits of the water standing at a higher level in it than the level of the water in the cold cistern. The expanded water goes mostly back into the cold cistern each time the range fire is lighted in the morning, while the difference in gravity of the hot and cold waters causes the former to reach a level of from 1 to 2 feet higher in the expansion pipe than the cold-water level in the cistern. Notwithstanding this explanation, the chief purpose served by the expansion pipe is that of admitting of the

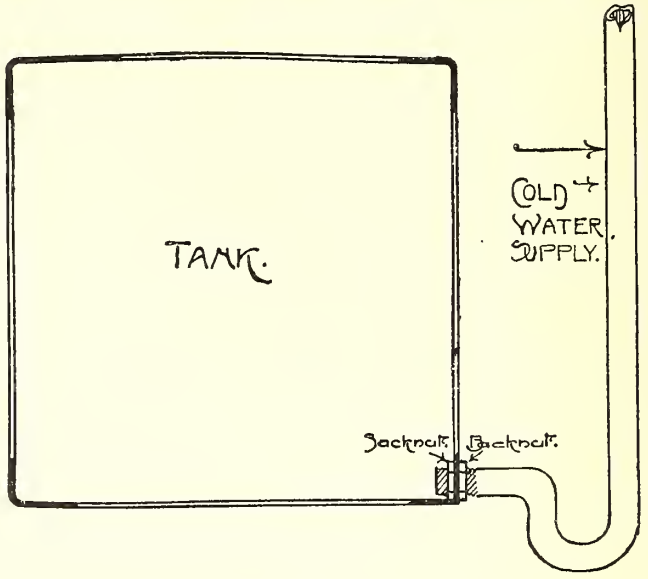


Fig. 40.

free escape of air from the apparatus. The filling could not be properly done, or at all, if the tank had no opening in its top; and if a temporary opening were made, to admit of filling, the air given off by the water when heated afterwards could have no opportunity to escape. It is sufficient if this pipe is carried 2 feet

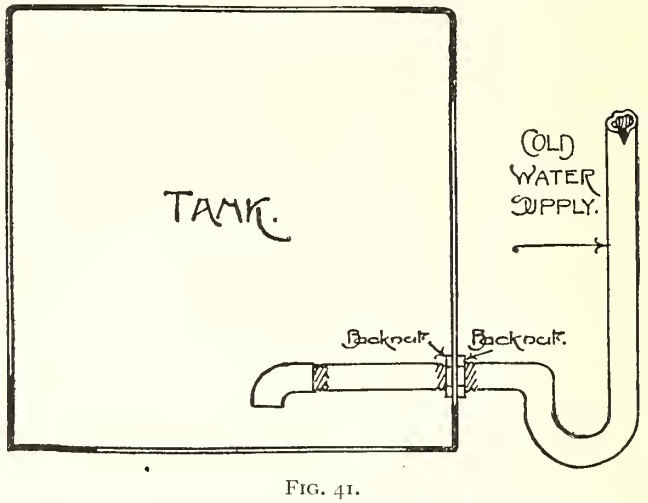


Fig. 41.

above the cold-water level in installations of medium height, and 3 feet where the apparatus extends up, say, 60 feet.

All draw-off services are branched from the flow-pipe, and, as previously stated, every effort should be made to have this pass as near as possible to the points where taps are to be. It is too often the case that a position

is located for the tank, and the pipes then run by the nearest route to it without regard to the points which the taps are to occupy. This commonly means branches of unnecessary length, with the subsequent annoyance of having to run off a good volume of cold water before the tap yields any that is hot. This is not a great fault at a bath, as most makers of good baths recommend that some cold water should be run in before the hot water is turned on; but at lavatory basins, usually having small taps, the annoyance seldom fails to bring complaints. This trouble can be reduced to some extent by using pipes (for branches) of a less size than the nominal measurement of the tap. Thus a $\frac{1}{2}$-inch pipe can be put to serve a $\frac{3}{4}$-inch tap, and this it will do quite well, as few $\frac{3}{4}$ inch cocks have a bore or way through them equal to the area of a $\frac{1}{2}$-inch tube. It is to be strongly recommended that the flow-pipe be run conveniently for the taps, as there is no satisfactory way of making branch circulations with this system of apparatus.

In regard to proportioning the parts of this form of apparatus, the following table will be found satisfactory. From the large number of failures that have been noticed, no hesitation need be felt in saying that by far the majority of them are due to a disproportion of parts. Sometimes the sizes of pipes are at fault, but usually it is the boiler and tank that do not agree. It is always one way, the tank too large for the boiler. There is no widely known rule for calculating the working capacity of range boilers (as there is with heating boilers), and, as yet, there is a marked tendency to overestimate the bulk of water they may be set to work with.

Shape of Boiler.	Width of Fire.	Capacity of Tank.	Circulating Pipes.	Number of Taps, including Baths.
	Inches.	Gallons.	Inch.	
Square, with arched flue .	9	24	1	2
Flued boot .	9	30	1	3
Square, A. F. .	10	28	1	3
F. boot . .	10	35	1	3 or 4
Square, A. F. .	12	32	1	3 or 4
F. boot . .	12	40	$1\frac{1}{4}$	4
Square, A. F. .	14	42	$1\frac{1}{4}$	4
F. boot . .	14	52	$1\frac{1}{4}$	5 or 6

The cold-supply pipe should be 1 inch in all cases, except with the smallest works, when it may be $\frac{3}{4}$ inch. Expansion pipes should be the same size as circulating pipes. Draw-off branches can be: lavatory basins $\frac{1}{2}$ inch, sinks $\frac{3}{4}$ inch, baths 1 inch.

CHAPTER IV

DOMESTIC HOT-WATER APPARATUS—THE CYLINDER AND CYLINDER-TANK SYSTEMS

The Cylinder System owes it name to the shape which the hot-water tank usually takes, and differs from that already treated in having the tank beneath all the tap branches instead of above them. It may be mentioned here that the cylindrical form of tank is used because of its pressure-resisting qualities. A square or rectangular tank of good quality, say, $\frac{1}{8}$-inch plate, is only tested to 5 lbs. to the square inch, whereas a cylinder made of this plate is tested to 25 lbs. per square inch. Pressure is easily calculated in this class of work by ascertaining the vertical distance from the cold-water level in the house cistern down to the position the tank is to occupy, and then allowing 1 lb. for each 2 feet 4 inches of the distance. Thus a vertical distance of 42 feet causes a pressure of 18 lbs. to the square inch to be felt. This would make the sides of a good quality square tank bulge out and possibly start it leaking, but quite a moderate quality cylinder will bear it without becoming distorted in shape. Most makers' price lists give the test pressures of their tanks, and the working pressures should not exceed these. For good work, one quality better than is absolutely necessary should be used, as this allows for wear and deterioration.

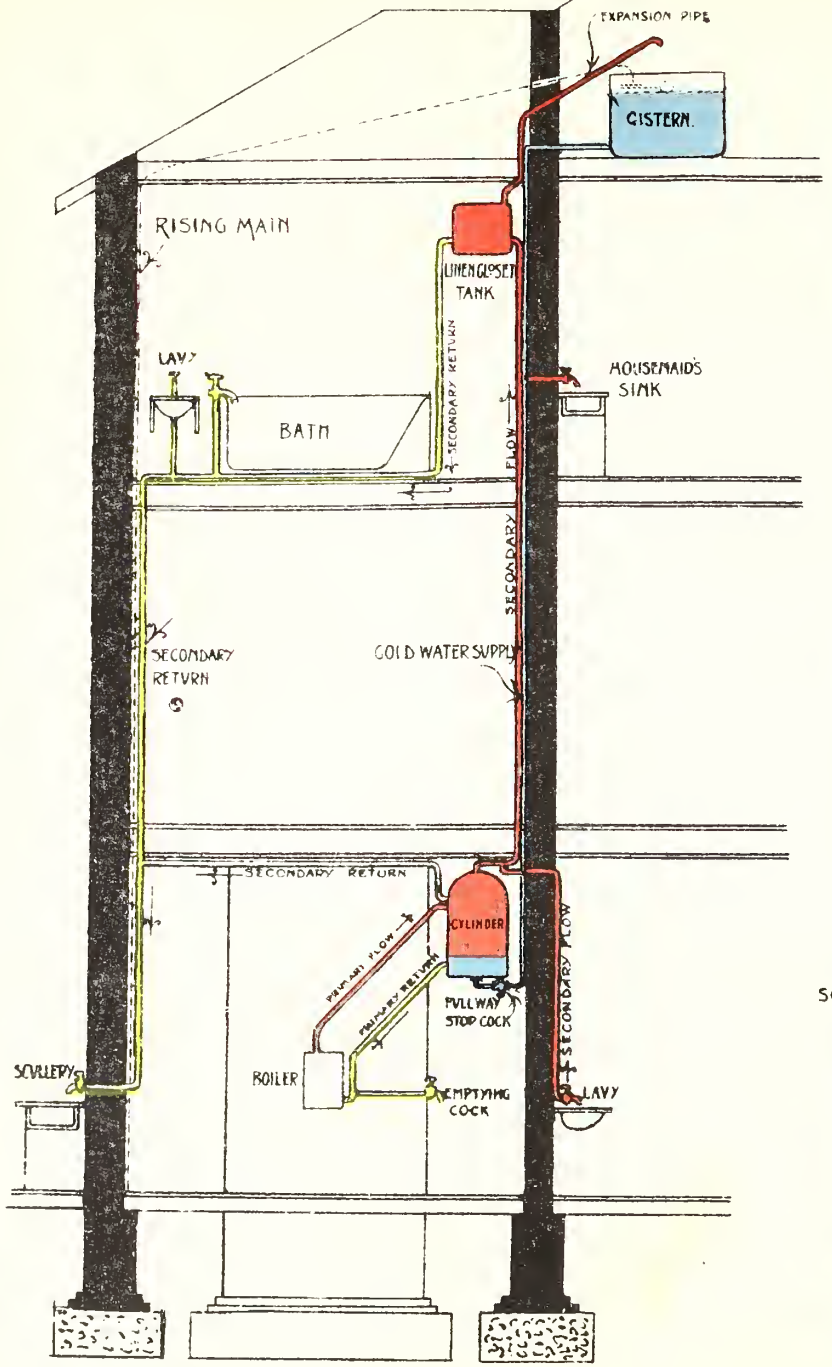
Fig. 42 illustrates the cylinder system of apparatus in it most simple form. The apparatus need never be of more complex form than this when the taps are all grouped near the cylinder, as will be learned directly.

Taking the details in the order adopted when describing the tank system, the boiler connections are arranged in the manner given there. The care to be observed in running the pipes from boiler to hot tank is also the same, and the two pipes terminate at different levels in the tank in much the same manner. The high termination of the flow-pipe serves to deliver the heated water from the boiler to the upper part of the cylinder only, in this case, as no draw-off branches are supposed to be taken from this pipe. Cylinders, as delivered from a maker's stock, nearly always have flanges provided for the flow and return connections, and these, placed one above the other, are situated as near the bottom as possible. This necessitates putting a bend or elbow on the flow connection, inside the cylinder, with a short piece of pipe extending upwards as shown. This internal pipe reaches to a point three-fourths the way up the cylinder, but when desirable or convenient the flow flange can be ordered to come three-fourths the way up the cylinder, outside, and the flow-pipe can then be carried directly to it, as shown by the pipe marked "Alternative method of running flow-pipe."

From the top of the cylinder an expansion pipe is carried up to above the level of the house cistern in the manner described with the tank system, but in this case it serves as the main hot-water supply pipe, being branched to the different points as shown. By this means the system obtains its special degree of safety in the fact that the cylinder cannot be emptied except by the emptying cock, which is for workmen's use only. Should there be a shortage of water from any cause, so that the taps yield no water, the cylinder remains full, and consequently no danger need be anticipated if the fire is used, even for a whole day. The contents of the cylinder may be evaporated by boiling, but this must take some time, and as the rule is to use no fire in the range when the hot taps cease to run, the risk due to shortage of water is reduced to a minimum.

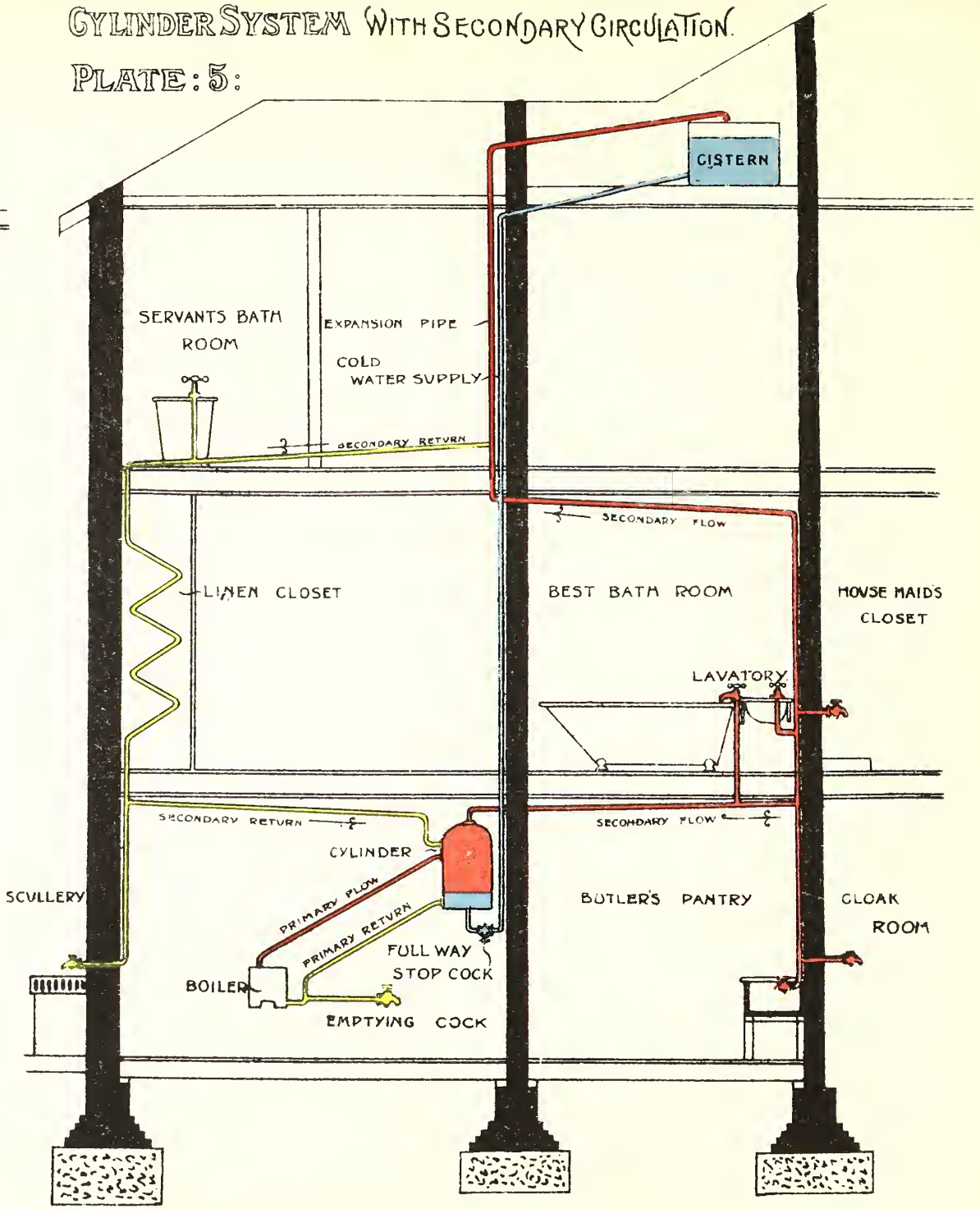
The cold-supply pipe comes down direct from the cistern, and is connected in the manner already explained in connection with the tank system. It is customary to put a stop valve in this pipe, near the cylinder, as there is then no need for workmen to traverse the house to shut the water off when boiler cleaning or effecting repairs. A very important matter concerning this pipe is its size. A glance at Fig. 42 will show that there is no store of hot water above the taps, and whatever water comes from them has its issue caused and governed by the pressure and flow of water down the cold-supply pipe. According to the size of this pipe, so the outflow at the taps will be. For small jobs, such as that illustrated, it might be a $\frac{3}{4}$-inch pipe (internal size), but in larger works 1 inch and $1\frac{1}{4}$ inch must be used. When the pipe is a long one the friction through its length, through the cylinder, and then up through the expansion pipe and branch, retards delivery quite seriously. This is the fault of the cylinder system previously referred to, for in an extensive apparatus the high taps have an outflow that is so slow as to be usually a source of complaint, and there is no remedy except in converting the system to that which is described a little farther on, which

CYLINDER-TANK SYSTEM.



CYLINDER SYSTEM WITH SECONDARY CIRCULATION.

PLATE: 5:



has an auxiliary hot-water tank at a high point. As stated, the cold-supply service should always be as large as possible, and it must not be choked or have its bore restricted at any point. Any stop valve in it must have a full straight way through it equal to the full area of the pipe.

The final detail appearing in Fig. 42 is the emptying cock. Without this the emptying of the apparatus for boiler cleaning, etc., is a considerable task. A $\frac{1}{2}$-inch tap will do, and a piece of hose can be slipped on the nozzle to run the water away to a sink or gulley. The

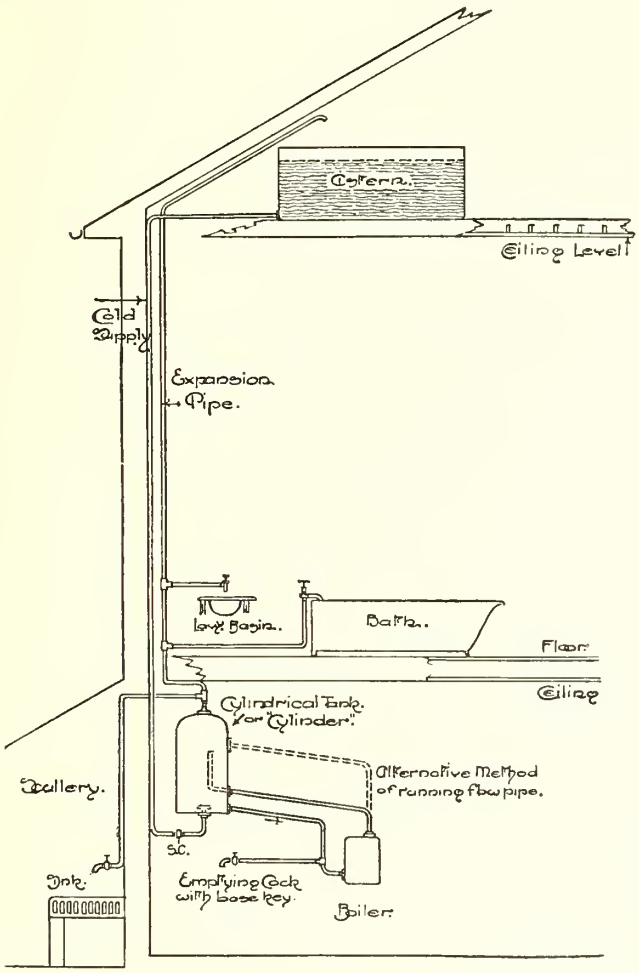


Fig. 42.

tap should have a removable key to be kept by the housekeeper, together with the key of the stop cock in the cold supply.

The emptying cock, which is only used when repairs are necessary, might theoretically be better placed so as to entirely empty the boiler, but this is rarely if ever done, it generally occupying the position shown on the return pipe—leaving a little drop of water in the boiler even when the rest of the system has been emptied by its aid.

In the many instances where taps are scattered about a building, and not all placed near the cylinder as in Fig. 42, the single-tube expansion pipe has the objection that at many points it entails a considerable quantity of cold or cool water having to be drawn from the taps before the hot issues. This is a fruitful source of complaint, whether in the kitchen-offices, or upstairs, and it has to be obviated in all good jobs. The customary method of doing this is to provide what is termed a "secondary circulation," this name being used to distinguish it from the circulation between the boiler and cylinder. It is a desirable thing, even if the taps are all in a line (but extending some distance away), and when the taps are scattered it serves a particularly good purpose.

The right-hand drawing on Plate V. illustrates an apparatus with secondary circulation, and the important points concerning it are as follow:—The secondary flow-pipe starts out from the top of the cylinder, and takes a course (with the necessary rise, as previously described) such as will bring it past one set or line of taps, and on reaching its highest point an expansion pipe extends up to the customary distance above the house cistern level. It might be said that the whole is an ordinary expansion pipe so far, similar to that shown in Fig. 42. At or near the level of the highest branch this secondary circulation proceeds towards and past the other taps, on its way back to the cylinder; but, from the point where the true expansion pipe extends up, the circulation ceases to rise, and is given a fall all the way down the cylinder. This will be seen in the illustration. The secondary flow therefore proceeds from the top of the cylinder up to the expansion pipe, while the secondary return extends from there back to the cylinder. As this circulation may have tap branches on it at any point it is important that both its ends should terminate where the store of hottest water is—which is at the top of the cylinder. It has been the custom to take the secondary return into a low part of the cylinder, or into the primary return, but there is only one correct place for it, and this is the upper part of the cylinder, about 4 to 6 inches from the top, according to the size of the apparatus. With the pipes ending thus all taps will be served with the hottest water, and whether there be little or much it can be drawn without having cold water mixed with it.

A reliable table of the proportions of parts in the cylinder system is given on opposite page.

Draw-off branches can be: lavatory basins $\frac{1}{2}$ inch, sinks $\frac{3}{4}$ inch, baths 1 inch.

In the previous pages it has been shown that, while the ordinary *Tank System* of apparatus is considered to be faulty, in the fact that the tank and pipes might be emptied should the cold water supply fail, the system is at an advantage in affording a good outflow of water at the taps, due to the tank being above the branches. The *Cylinder System*, on the other hand, quite overcomes the fault described above, but it introduces a new one in usually having a sluggish, sometimes very

bad outflow at high taps, due to the absence of a tank above the branches. With the idea of avoiding the faults and gaining both advantages the CYLINDER TANK combined system has been designed.

Shape of Boiler.	Width of Fire.	Capacity of Cylinder.	Circulating Pipes from Boiler.	Expansion Pipe (or circulation above Cylinder, when used).	Number of Taps, including Baths.
	Inches.	Gallons.	Inch.	Inch.	
Square, with arched flue.	9	24	1	$\frac{3}{4}$	2
Flued boot .	9	30	$1\frac{1}{4}$	1	3
Square, A.F.	10	28	1	1	3
F. boot . .	10	35	$1\frac{1}{4}$	1	3 or 4
Square, A. F.	12	32	$1\frac{1}{4}$	1	3 or 4
F. boot . .	12	40	$1\frac{1}{4}$	1	4
Square, A. F.	14	42	$1\frac{1}{4}$	1	4
F. boot . .	14	52	$1\frac{1}{2}$	$1\frac{1}{4}$	5 or 6

The left-hand drawing on Plate V. illustrates the details of this as usually erected, and it will be seen to resemble the cylinder system of apparatus with secondary circulation, except that a tank is inserted at a high point and the expansion pipe is connected to it. In an apparatus of this kind the cylinder would not be so large as that ordinarily used, as the customary proportion of parts must be maintained. If a 50-gallon cylinder would be the correct size if used alone, then with the combined system this must be divided between the two reservoirs. As a rule, it is found best to have a little more water in the cylinder than the tank, and for 50 gallons a 30-gallon cylinder and 20-gallon tank would be correct. The only purpose of the tank is to ensure a good outflow at open taps, so that its use is limited to the brief periods when taps are opened.

It is sometimes thought that the taps on the flow side of the tank must be served more quickly and always with hotter water than those on the return, but this is not so in practice. The hottest water is always gathering up in this tank, and what is not there must be in the upper part of the cylinder, therefore both secondary flow and return have about the same communication with the hot water that is available.

It is very desirable that the upper tank be well covered to prevent loss of heat. This will, as a rule, ensure a supply of warm water being available at early morning hours, as the hot water will all gather up at this high point at night.

CHAPTER V

HOT-WATER HEATING WORKS—LOW PRESSURE

In affording warmth to buildings by means of hot water all the methods and systems adopted rely, for efficacy, on the action of Convection, or "obtaining a circulation," as it is termed. Without devoting some study, or at least consideration, to this detail of the subject the engineer must often fail for want of knowing the principle that his work is based on. A full explanation of the action of Convection has already been given, and it is recommended that the student master this information; for although the explanation is associated with hot-water works for domestic supply, the principle involved is just the same, while the suggested models and the experiments that may be conducted are equally useful and instructive. Taking, therefore, this information as an introduction to the subject now being dealt with, the erection of practical works may be described.

There are three distinct systems of low-pressure hot-water heating works, and two of high-pressure. Low Pressure is a term applied to an apparatus which has an open expansion pipe—a free blow-off as the London Building Act describes it; while the High-Pressure apparatus consists of one or more circuits of pipe, which are sealed and have no open outlet whatever. The three low-pressure systems are the *Two-pipe*, *One-pipe*, and the *Overhead*. All may have radiators as the heat distributing surface (in good interiors), or large cast pipes may be used (in warehouses, etc.). Many works are erected which combine two or all three systems, more or less. It will be seen directly that one or the other may be best to adopt according to conditions. The two-pipe system is the oldest, but there are numbers of two-pipe jobs being done at this moment by quite up-to-date engineers. The one-pipe system is favoured most, perhaps, but this is largely due to its meeting general requirements more often than the others. In the writer's own house the apparatus is partly one-pipe and partly overhead work, and the arrangement was not a matter of choice but of absolute necessity. A two-pipe installation was practically impossible.

The Two-pipe System

In Fig. 43 is illustrated a simple apparatus which will serve to describe the chief points of the Two-pipe System from. Each radiator, it will be seen, communicates directly with a main flow and return service, and from this detail the term "two-pipe system" is obtained.

A main flow-pipe is taken from the boiler, and is carried so as to pass as near as possible to the points where the radiators are to be placed. Alongside the flow is carried the return pipe, the two pipes being alike in all general respects except for their terminating at different levels in the boiler. It is also the custom, when the pipes run in a horizontal direction, to let the flow be above the return. This is not necessary for the circulation, but has become a rule in the trade, so that when pipes are inspected the upper pipe is always assumed to be the flow.

In the example (Fig. 43) it will be seen that the main flow is branched near the boiler, for the purpose of serving some radiators on the right side of the illustration. This is quite a customary and proper plan, but when a flow branch comes as near the boiler as is shown it would be as well to let it start from the boiler direct as a distinctly separate circulation. Assuming, however, that the boiler has been delivered with but one flow-pipe tapping, then the flow branch may be arranged as illustrated. It may be asked why the main circulation has not been carried up to the radiators nearer the boiler (on the right of the illustration) and the branch to the distant ones. The reason is that distant circulations must always be favoured, and the connections, as shown, favour the circuit up the left side of the illustration. A continuing vertical pipe is always favourable to a better circulation than a tee branch with a horizontal outlet.

The returns, it will be noticed, do not branch or join into one another, but enter the boiler independently. An excellent rule to remember in this work, to ensure getting the most uniform working possible with branched circulations, is to calculate that a flow-pipe may be branched to any reasonable extent and a return pipe never. Occasionally returns have to join, but no experienced engineer does this without having some doubts as to getting the best results. It is probable that keeping the returns separate admits of branching the flow, but it is certain that keeping flows separate will not allow of joining the returns. Perhaps the rule should be, join the returns as little as possible, and avoid doing so entirely unless it be absolutely imper-

ative. Joining the returns does not necessarily imply failure, but it hazards it and usually limits the success. be got there, but it will do at the head of a branch circulation, or in case of necessity it may be at any

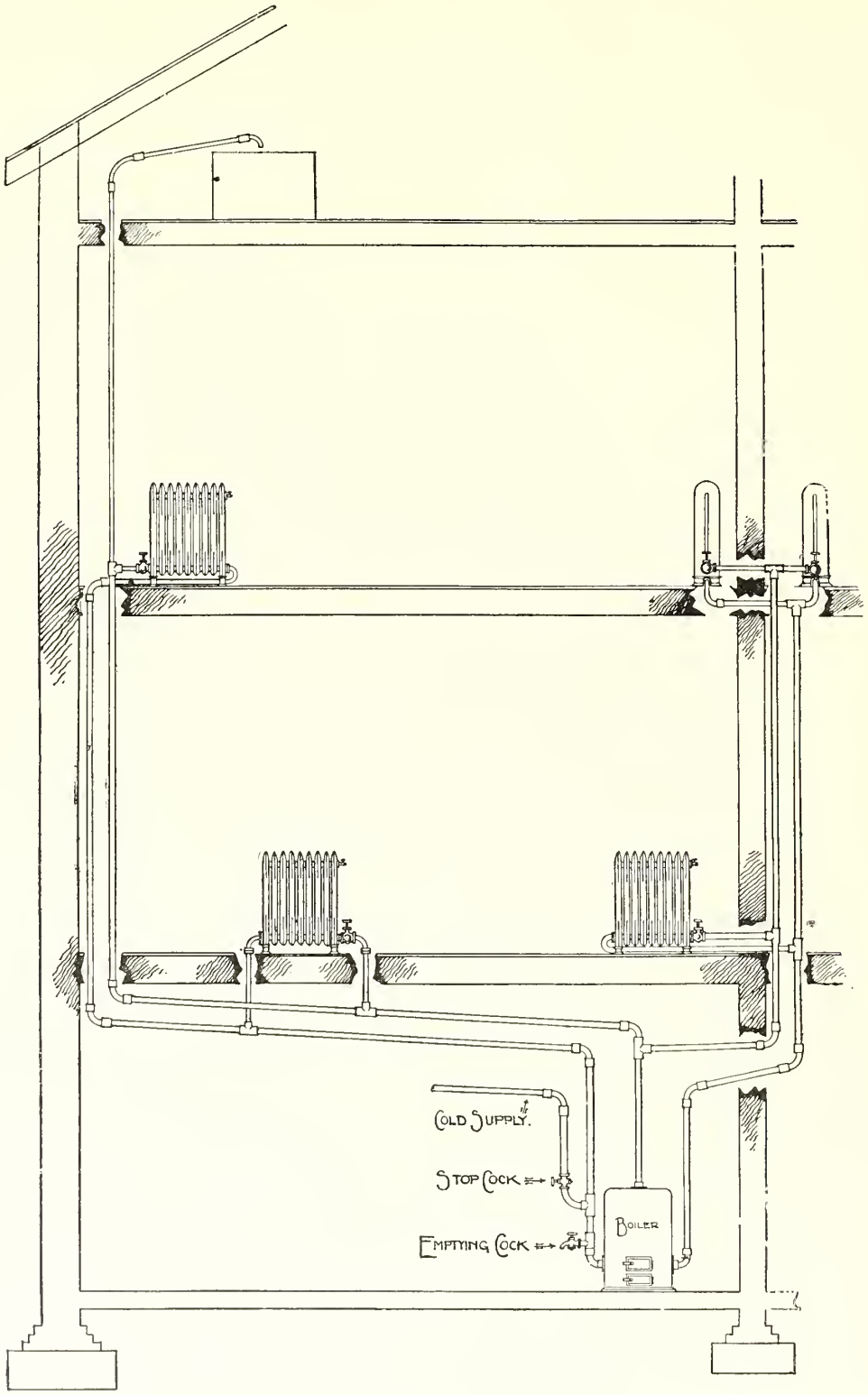


FIG. 43.

The expansion pipe is shown extending from the top of the main flow-pipe, a good place for it when it can lower point on the main flow-pipe. If desired, more than one expansion pipe can be used, but it is important

to note that if the expansion pipe or pipes do not occupy high points it is necessary that radiators be there to receive the air. An expansion pipe is really an air pipe, and at all high points there must be air pipes or radiators. A radiator will receive a good volume of air without ceasing to heat properly. As explained on a previous page, water discharges or releases a certain amount of air when it is heated, and in domestic hot-water works the air question requires full consideration, as the frequent changing of the water makes the supply of air almost continuous. With heating works the change of water is practically *nil*, therefore the collection of air, after discharging that from first heating, is very small.

Realising that the air trouble is small, after the water has been well heated and deprived of the air it carries, attempts have been made to do without an expansion pipe. Expanded water could find its way into the cold cistern, as it usually does, and safety from explosion would be had in the open cold-supply pipe and the safety valve on the boiler. The attempts have failed, however, and the writer, like others, has experienced the failure. On heating the water in an apparatus minus an expansion pipe there occurs what can only be described as a "swelling back" in the cold cistern, and if the cistern is only of moderate size there will be an overflow. It is not caused by expansion, for it occurs when the water is no more than warm, and it happens so suddenly and swiftly that the water will get over the edge of the cistern although it may be provided with an overflow pipe. No good explanation has been offered as to this phenomenon, but a reliable remedy lies in the use of an expansion pipe.

The cold supply is not shown intact in Fig. 43, as it is not always run in the same way. The important detail is that this pipe should always join the boiler (at a low point), or a return pipe at a point close to the boiler. For economy's sake the cold supply is sometimes taken into a return at a high point, but in the majority of cases this brings about trouble by locking air in the apparatus either at the time of filling or refilling. In some works the engineer has to provide the cold-supply cistern, in which case he puts in one of the least necessary size, and places it as closely over the highest radiator as he can, so as to economise in the length of the cold-supply pipe and the expansion pipe. When possible, however, he utilises the house or general cold cistern of the building, and instead of bringing down a separate cold-supply service from cistern to boiler, he takes a branch from one of the services that come down for some other purpose. This is not to be objected to, as it introduces no element of a dangerous or troublesome character.

Quite a small pipe will serve the boiler, as it uses such a small quantity of water; but the supply cistern, if the engineer provides it, must bear in size some relation to that of the apparatus. When the apparatus is newly filled with cold water there only requires to be 2 or 3 inches depth in the cistern, and the remaining space in the cistern must be large enough to accommodate the water of expansion The expansion of water when heated from 39° to 212° Fahr. is 1 in 24—24 gallons becoming 25; and as this range of temperature is by no means impossible, an allowance equal to 1 gallon for every 24 in the apparatus should be provided in the cistern. Some difficulty lies, however, in calculating the contents of the apparatus, but for arriving at a figure with reasonable quickness it may be taken that 5 square feet of radiator surface represent a gallon of water, that 4-inch pipe holds half a gallon per foot, 3-inch pipe one-third of a gallon, 2-inch pipe one-eighth of a gallon, while mixed smaller sizes hold about one gallon to 20 feet run. In arriving at the size of the cistern it is then only necessary to allow that $6\frac{1}{4}$ gallons occupy a cubic foot of space.

The radiator branches are taken from tees in the flows and returns as shown, and each radiator is usually given a stop or regulating valve. Whenever possible the connection should be effected as with the radiator Fig. 48, as by means of an angle valve and a union elbow a very neat effect is produced without any pipes being visible. This is almost always possible when the main pipes run beneath the floor on which the radiators stand; and it is of the greatest importance in residence works and in other good interiors, such as those of hotels and similar buildings, that the best possible effect be produced. There are numbers of people, especially of the gentler sex, who are prejudiced against hot-water heating wholly on account of the "ugly pipes." There can be no doubt that much work that has been done, and done recently, has, by its appearance, greatly retarded the progress of this mode of heating. The radiator has been of enormous help, but there are fitters who can make it unsightly by its connections.

It is the best plan, in connecting radiators, to have a union to each connection,—that is, a union valve and union elbow. This may not facilitate fixing very much, but it greatly facilitates removal and refixing. There are few jobs in which, when the hot-water engineer has finished his work and tested, he is not asked to take down all his radiators to admit of the decorators working on the piece of wall and skirting behind each of them, and when this is done the radiators have to be put back again. This should always be remembered, particularly when giving an estimate for work to be done a long distance from the shop. Figs. 44 and 45 illustrate a union angle valve and a union elbow. Both can be obtained from customary sources either in plain gun-metal or nickle-plated.

Each radiator has to be provided with an air vent, and as a rule an air cock is used, such as is shown near the top of each of the radiators in Fig. 46. The best air vent is an open pipe, as it does not require attention, but in most cases pipes are out of the question, and cocks, fortunately, do not need opening often after the

first heating up. The writer has several radiators, the air cocks of which are only opened once yearly.

All pipes in heating works are carried with a rise from the boiler of at least 1 inch in 10 feet. The need

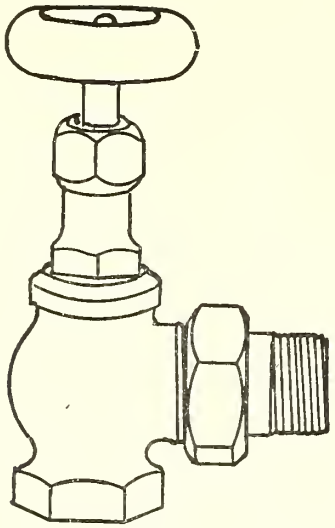


Fig. 44.

of the rise, to enable air to get away, is specially marked in these works, as there are no draw-off cocks to disturb the air (by the rush of water they occasion) as there is with hot-water supply installations. It is quickly noticed, when experimenting with a glass model apparatus, how persistently the bubbles of air hang in the horizontal pipes. The circulatory movement of the water does not disturb them even though the water movement is in the same direction as the air should go. This is so noticeable that there is a strong feeling that the customary minimum rise of 1 inch in 10 feet should be abandoned and 1 inch in 5 feet substituted. It is important that the air get away freely, for although it may not stop a circulation it will

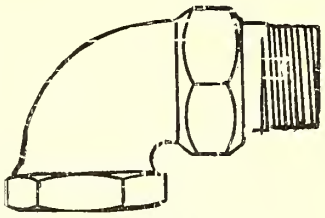


Fig. 45.

certainly check it by being an obstacle which about half closes the pipe.

Sizes of Pipes for the Two-pipe System of Low-Pressure Hot-Water Heating Works.

Size of Pipe.	Will supply this Area of radiating or heat-losing Surface.
4 inches	1300 sq. feet
3 ,,	750 ,,
$2\frac{1}{2}$,,	500 ,,
2 ,,	270 ,,
$1\frac{1}{2}$,,	150 ,,
$1\frac{1}{4}$,,	75 ,,
1 ,,	45 ,,
$\frac{3}{4}$,,	20 ,,

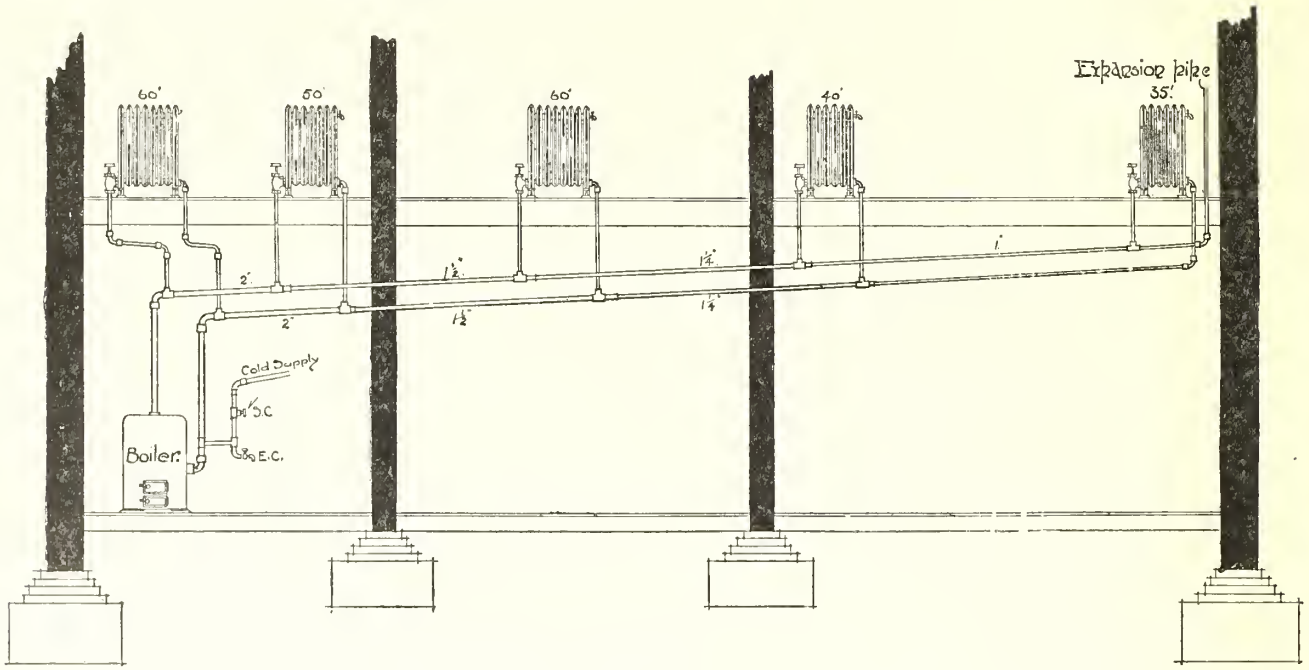


Fig. 46.

The above figures are for horizontal basement pipes; when the work is largely vertical (as that shown in Fig. 43 would be considered to be) a size less pipe may be used, *i.e.* 270 feet of surface could be put on to $1\frac{1}{2}$-inch pipes. There is such a difference in the speed of circulation in horizontal and vertical pipes that the latter

will keep the radiators served nearly twice as well as the former. The sole purpose of the pipes is, of course, to keep the heat-losing surfaces supplied sufficiently fast that they may always be as near the temperature of the water in the boiler as possible. It must be borne in mind, when calculating the area of heat-losing surface, that the circulating pipes are heat losers, and their surface must be included if they are not well covered to prevent loss of heat.

In planning the sizes of the pipes it is possible in this system of apparatus to graduate them to the work they have to do. For instance, if the whole heat-losing surface amounted to 250 feet (on horizontal mains), the pipes leaving the boiler would have to be 2 inches, but they need not extend to the distant work in this size. They need only be 2 inches while the surface to be supplied is between 150 feet and 250 feet, and when sufficient work is passed to leave the remaining heat-losing surface less than 150 feet the mains can be reduced to $1\frac{1}{2}$ inch, and so on. Fig. 46 will give an idea of this.

The One-pipe System

In Fig. 47 is illustrated a simple apparatus from which the chief points of the One-pipe System may be described. Each radiator, it will be seen, is connected to a single main pipe, and from this detail the term "One-pipe system" is obtained; but it is not that the radiator is connected by a single branch pipe (as it is with the one-pipe system of steam heating), for without flow and return branches the water will not circulate through the radiator.

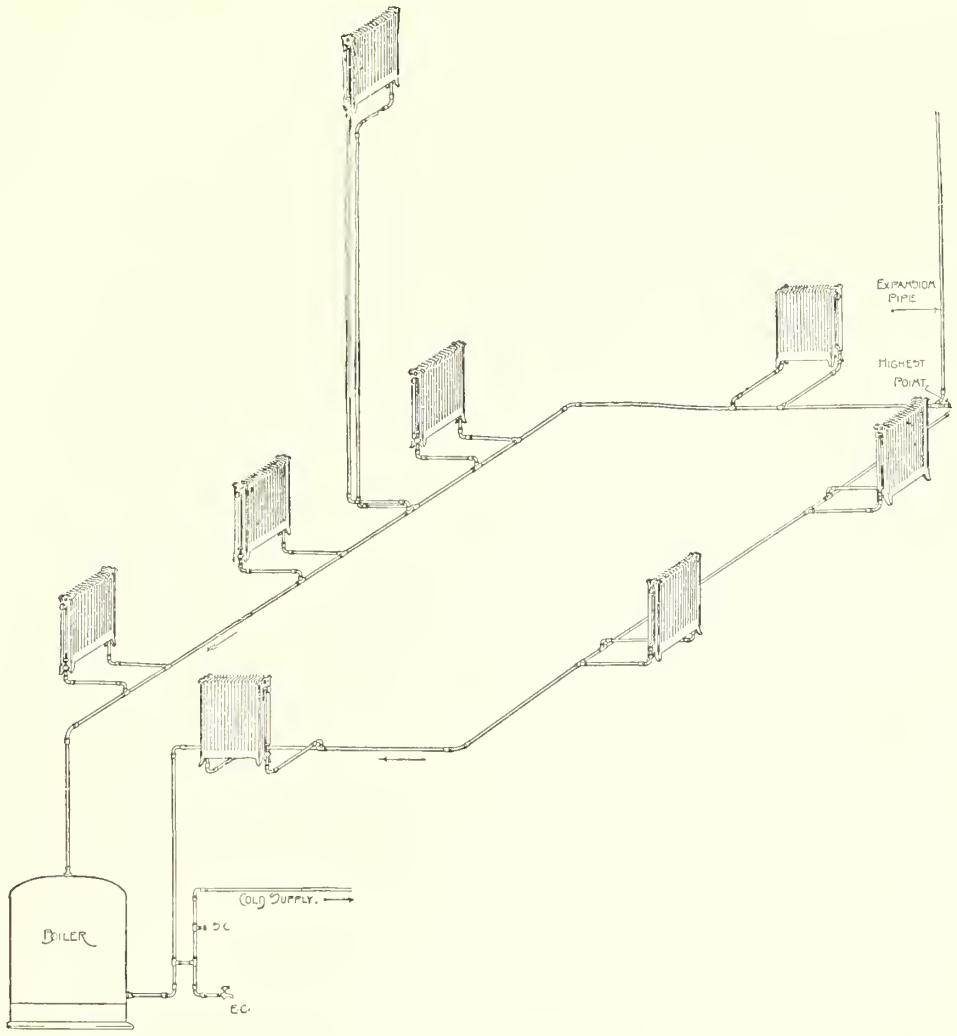


Fig. 47.

The peculiar detail of the apparatus—peculiar as compared with the two-pipe system, is that when the radiator has dissipated what heat it can from its water, and so made it of less heating efficacy, this water is returned to the main pipe which carries the hottest water, and which corresponds with the flow main in the other system. It will be found, however, that this does not prejudice the heating of the remaining radiators, for, in the first place, the water which passes through one or even two radiators is still sufficiently hot to be useful; and secondly, it is found that the cooler water

arranges itself as a lower stratum, beneath the hotter water, in the pipe.

As the single main carries both flow and return waters, and all there is of them, it follows that it must remain its full size from beginning to end, and cannot be graduated as is possible with the two-pipe system.

The horizontal main is carried around the basement space under the building, passing nearly beneath the points where radiators are to come above, but it should not come immediately beneath the radiators. Assuming that it is a square-shaped building, requiring radiators against the outer walls in rooms or offices, then the main would be suspended from the basement ceiling, about 4 to 6 feet distant from the walls, for a reason connected with the radiator branches, as will be explained. The main circulation is given a rise from the boiler of at least 1 inch in 10 feet, as with other systems, but as it is one continuous pipe there has to be a point chosen for the main to reach its greatest elevation, this being, as a rule, about half-way round the circuit. In Fig 47 this "highest point" is marked, and the flow is given a rise from the top of the boiler to this point, while the return descends from here back to the boiler.

As stated, the highest point in a one-pipe horizontal circuit is, as a rule, arranged to come about as far out from the boiler as possible, thus making the flow and return of the circuit of about equal lengths. It does not matter if the flow is a little longer than the return, but, theoretically, if there is any difference at all, the flow should be shorter and have the least radiation on it. It is as well to arrange it so when possible.

At the highest point the expansion pipe is usually placed to relieve the circuit of any air that may collect in it, which would naturally gather here. It is essential that there be a way for the air to escape out of the pipe, but if the "highest point" and the expansion pipe cannot be located together, then the expansion pipe can be placed elsewhere on the flow-pipe, provided a radiator is placed on the high point for air to collect in, and to be allowed to escape periodically by opening its air cock. As previously stated, the collection of air in these works is not great after the first heating up, and although it may be sufficient to have a bad effect at the high point in a pipe circuit, it is not enough to be troublesome if vented into a radiator. The latter will take ten times as much air as a pipe before its efficacy is impaired.

The customary method of connecting and running the radiator branches is shown in Fig. 48, and this illustration will show how it is that the main circuit does not need to be run immediately beneath the points which the radiators are to occupy. The reason for keeping the mains from directly under the radiators is to admit of making what are known as "Swing connections." Long straight runs of pipe, such as these mains may be, give a very distinct push and pull (lengthways), as they expand and contract with heat and cold, sufficient in any fair sized installation to seriously strain, if not break, connections made with straight branches which are more or less rigid. The method of connecting, illustrated by Fig. 48, is certainly more expensive than straight branches, either vertical or horizontal; but unless the job be one with short mains, or mains that are continually breaking away from a straight line, this method of running the branches must be followed.

It will be noticed that one branch, the flow or that nearest the flow connection of the boiler, is taken out of the top of the main by a tee looking upwards. This is to ensure the radiator being served with the hottest water from the top of the main. The return is connected horizontally with the idea of delivering the used and cooled water as low down in the main as possible. The idea is a correct one, but it must be admitted that many jobs are done with both tees looking upwards, and the result appears to leaving nothing to be desired.

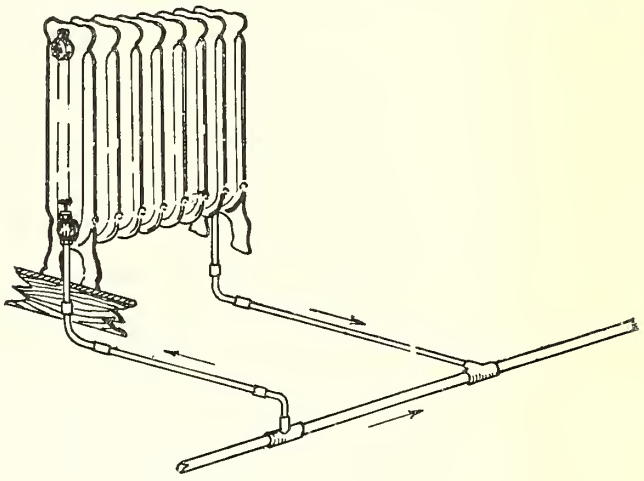


Fig. 48.

A horizontal connection that can be recommended is that to the flow branches of the first fourth of the number of radiators on a circuit. Thus, if twelve radiators were being connected to one line of pipe, it is a good plan to let the first three out from the boiler have horizontal connections to both their branches. It will be quite understood that the first radiator has the hottest water delivered to it always and in any case, so that a horizontal connection delivers as good water as any other. With second and third radiators on a fair sized circuit the water in the main is practically as hot as when it passes the first radiator, so that these again cannot be served badly by horizontal connections. The advantage gained is with the later radiators, as it may be assumed that some of the hottest water travels along the top of the pipe past the first three pairs of horizontal tees, and so arrives at the fourth radiator as hot as it came from the boiler. By this means the fourth is served much like a first radiator ordinarily is. Some such plan of getting the hottest water quickly

along to the distant radiators is worth following, as a little fault which this one-pipe system has is the considerable difference in temperature between the first and last radiators when lighting up or heating up at any time.

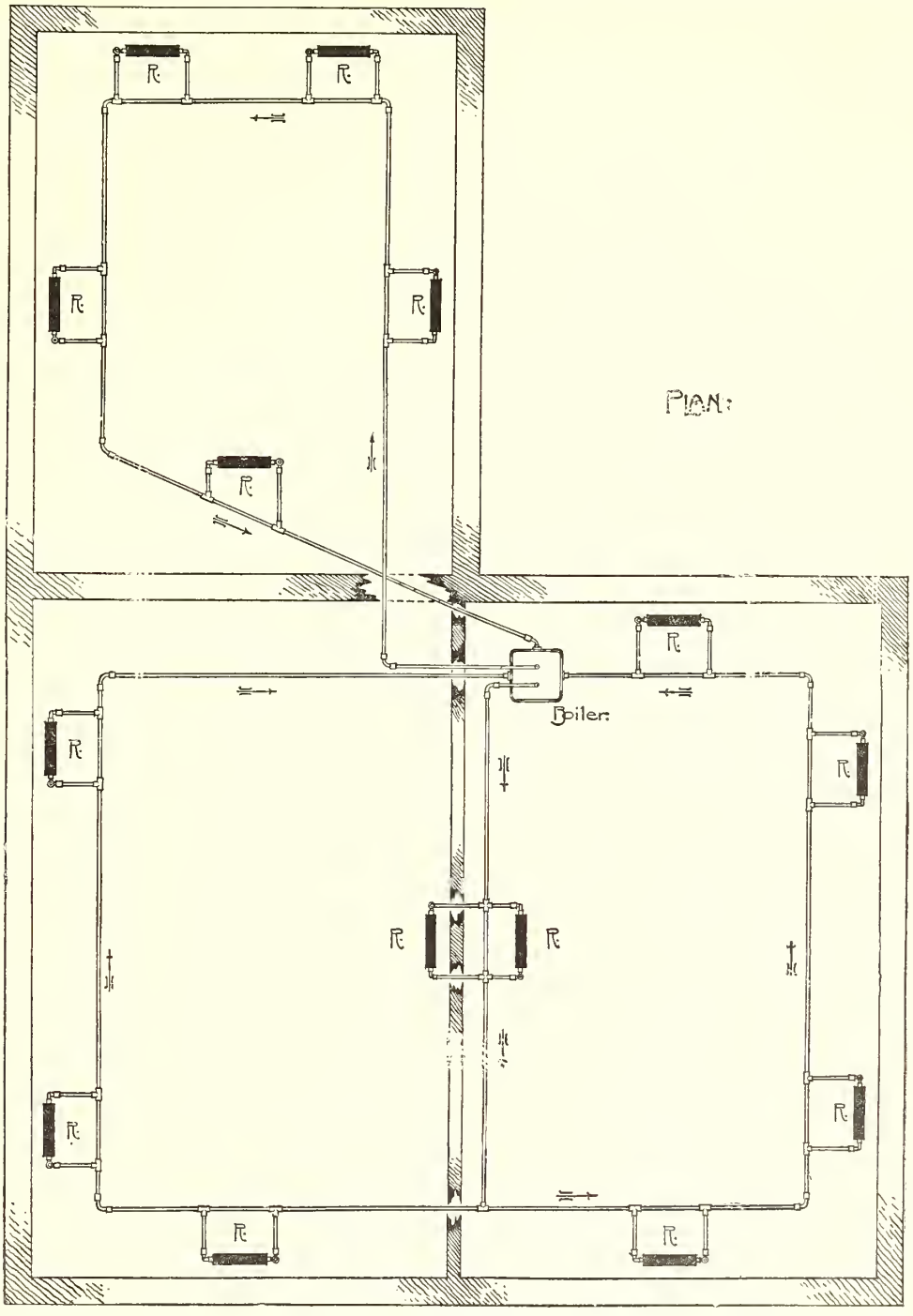


FIG. 49.

When all are hot, the radiators heat with agreeable uniformity (if all the conditions are correct), but, as stated, when heating up the first radiators take all the hot water and keep the end radiators cool for some time.

A good plan for obtaining uniform heating amongst the radiators is to divide them up into two or more circuits. When the radiators all stand around the outer walls of a square building there is always a temptation to run a single circuit to take the lot, but when the work is more broken up the circuit can be broken up also with advantage. Fig. 49 will show what is meant. In this, one circuit takes five radiators, while another consists of one flow with two returns, these twin circuits taking nine radiators together. In

this work, as with the two-pipe system, there is rarely much objection to branching a flow main, but every effort should be made to let the returns enter the boiler separately.

In this country the one-pipe system is not used largely when there are radiators on one or more floors above the ground floor, but there is no reason why the system should not be adopted in such cases, if the general

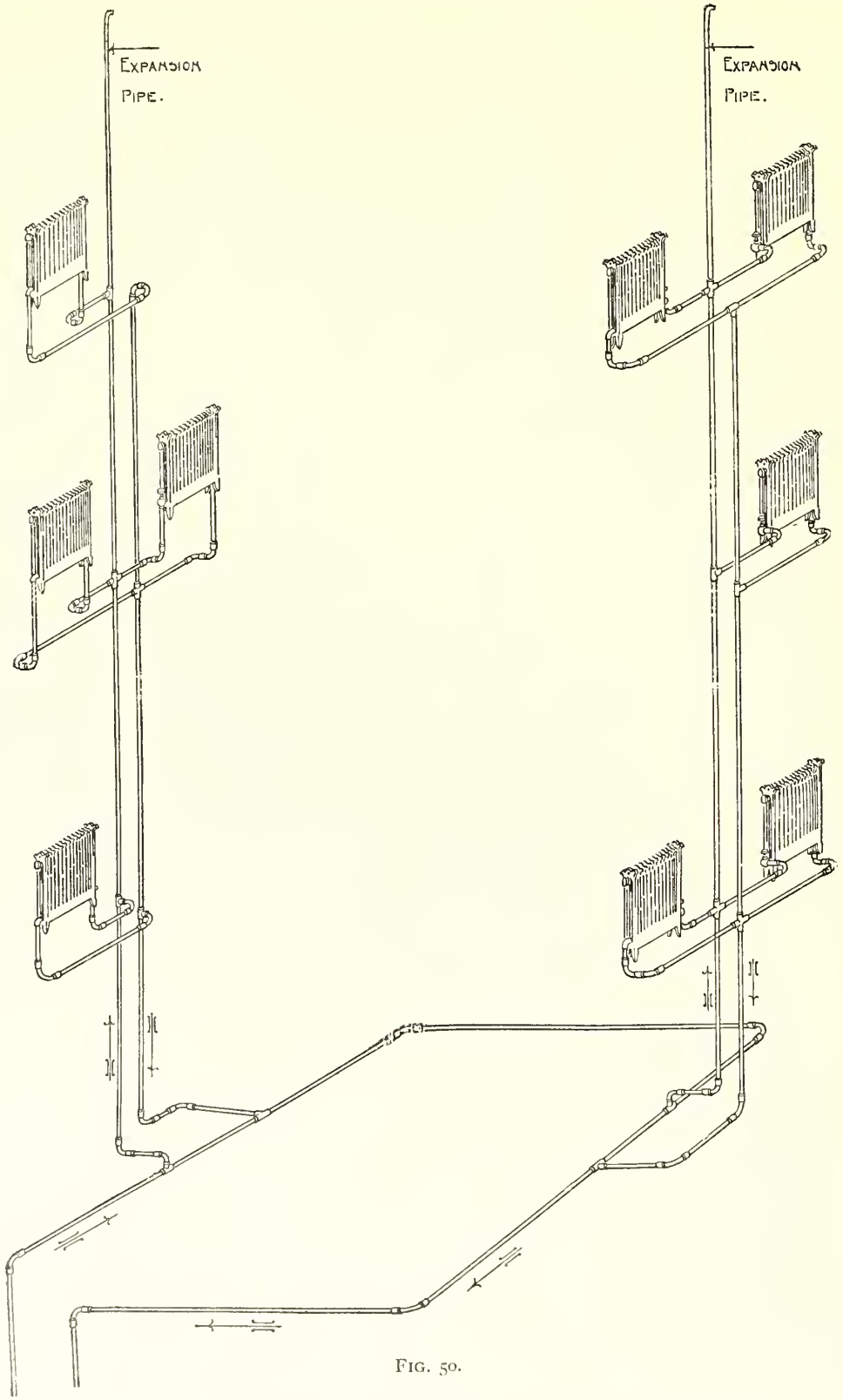


Fig. 50.

conditions make it desirable. In America the two-pipe system is almost unknown, and when the overhead method is not resorted to the one-pipe circuits have pairs of "risers"—rising branches—such as are shown in Fig. 50, to serve whatever upper floors need warming. There are no objections to this,—in fact, it works quite satisfactorily if the apparatus is properly proportioned, the mains in particular being of full size, as this helps to hasten the arrival of the hot water at the distant risers and to keep them well supplied.

The cold-supply service is arranged and connected as with the two-pipe system, and further description is therefore unnecessary.

The particular good features claimed for the one-pipe system are, firstly, that "short-circuit" is not possible. This term has been used when heated water circulates up to a certain point in a long run of pipes, and returns from this point to the boiler, leaving the water in the more distant parts of the run undisturbed and cold. This is considered to be possible with the two-pipe system, as each branch provides a means for the heated current to get from the main flow to the main return and so back to the boiler. It is a fact, too, that short-circuit has been experienced with two-pipe work, but only when the parts have been badly proportioned or the runs arranged without regard to correct practice. In other words, it is quite true that the one-pipe system prevents short-circuit, but it is quite preventable in any other system. A second advantage claimed is the reduced cost, this being based on the fact that one main pipe serves where two might otherwise have to be used. The two-pipe system certainly requires two main pipes to be run, close together, in whatever direction the radiators may be; and this entails extra expense compared to one-pipe work, when the radiators all lie round the outer wall of a building. At other times, however, such as when the radiators lie in a nearly straight line, the two-pipe system is the cheaper, as there must be two main pipes carried whatever the system, and with two-pipe work the pipes can be reduced in size as the work is passed, while the one-pipe system must have full sized mains all the way. It may be said that each is the cheaper under certain conditions, but the one-pipe system most often.

Sizes of Main and Branch Circulating Pipes, One-pipe System of Low-Pressure Hot-Water Apparatus.

Sizes of Pipes.	Area of radiating or heat-losing Surface.
4 inches	1300 sq. feet.
3 ,,	750 ,,
2½ ,,	500 ,,
2 ,,	250 ,,
1½ ,,	150 ,,
1¼ ,,	75 ,,
1 ,,	45 ,,
¾ ,,	20 ,,

The Overhead System

Fig. 51 illustrates the Overhead System, with details of its special features, as will be explained. In theory, and to a great extent in practice, it is considered correct, to favour the circulation, to let the contents of the flow-pipe be as hot as possible, while the return pipe only should carry cooled water; and the flow should have the least volume of water in it. Fortunately, the circulation never requires to be favoured to this extent, but the fact remains that the idea is a correct one, and on this account the overhead system is thought to have a more perfect action than any other. It probably does, but this is largely due to there being so much vertical pipe, as a rule; and very little experience shows that, with vertical work, the circulation frequently wants severely checking to favour any horizontal section of the apparatus there may be. Correct as the principle of the overhead system is, it may be said to be unnecessarily so.

It will be seen that the flow main proceeds by the nearest possible route to the highest point, and carries no radiator branches on it. As it exists solely to serve the returns and their radiators, it should be well covered to prevent loss of heat. It carries the hottest water, and can lose heat the fastest. At its highest point the flow is branched in one or more directions, and from here all pipes are carried as returns. The returns can be branched (like flows) as they descend, but, as with other systems, they should all join the boiler separately if possible. The expansion pipe can be at the head of the flow-pipe, as shown, or may be at any other high point, provided a radiator receives the air at the head of the flow-pipe. This has been already fully explained.

Attention is called to the return circuit on the left side of the illustration. It will be seen that it ends running at (or it may be just beneath) the floor level that the boiler stands upon. It is an advantage claimed for this system that no boiler pit is needed; that the boiler may be on the same level as some of the rooms to be heated. In riverside premises this is a good feature, as basements or boiler pits are commonly impossible. In city business premises, too, the basements are often made valuable use of as suites of offices, or stock-rooms, level with the boiler-room, and require to be heated. This is easy of attainment, as the circulation is such that the fact of the returns dipping, say, two feet, or even more, below the boiler has no prejudicial effect on general efficacy.

The radiator branches can be connected in any of the customary methods, but where the returns are long straight runs the branches should be run so as to "swing" a little to the push and pull of the main return as it expands and contracts. If the branch is a straight horizontal pipe, then the radiator should not be nearer than about 4 feet to the main; when nearer, some method of cranking the branch must be

adopted to give to the strain. On the right of the illustration one radiator is shown with top and bottom connections at one end. If appearance will admit, this is a favourite connection to single vertical mains, as it is the best, theoretically, and no air cock is needed

the work, then each return would be of a size to suit the radiation upon it.

A useful purpose to which the overhead system can be put is in heating suites of rooms on one floor. These may be offices or residential flats, and as the floor

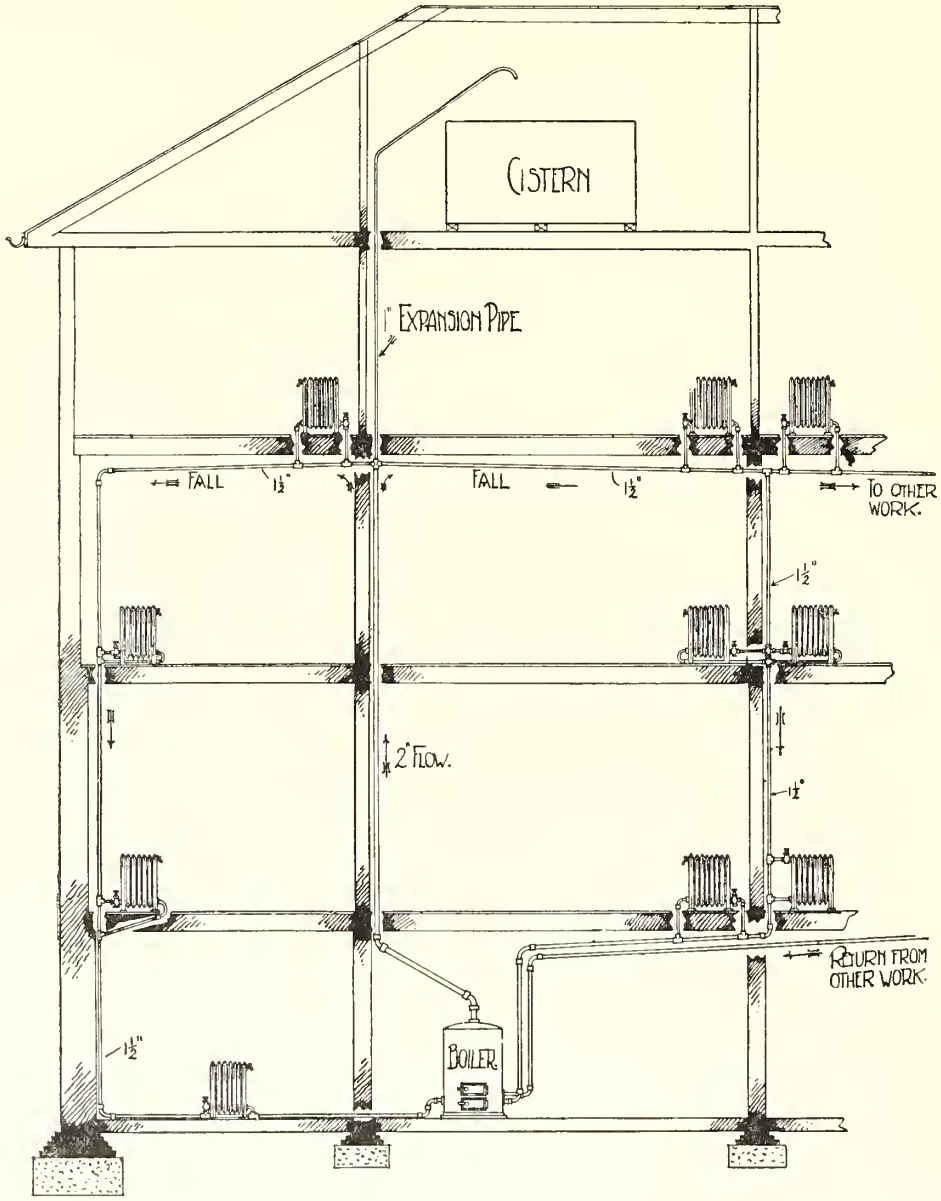


FIG. 51.

to the radiator. What air may collect in the radiator escapes through the upper branch.

If the installation consisted of one circuit—one flow and one return—the pipe would have to be of one size throughout. It would, in fact, be an apparatus on the one-pipe system, but with vertical mains instead of horizontal. When the returns are branched or divided, as shown, then the pipes may be graduated in size, as described with the two-pipe system. The flow-pipe would be of the full size needed to carry the whole of

beneath is probably occupied by someone else and not available for the boiler, the whole must be confined between one floor and ceiling level.

Fig. 52 illustrates how this is done, but it will be quite recognised that there has to be a ceiling pipe and a floor pipe, necessitating two casings (or being left visible). The ceiling pipe, too, cannot be kept close up, as it must be below the water-line in the supply cistern. This can only be overcome by either finding a higher place for the cistern, or by arranging with the

tenants of the floor above that the cistern be in one of their rooms, in a kitchen apartment or in a cupboard.

Horticultural Hot-Water Work

In heating glass-houses, it may be considered that the radiating surface always consists of cast-iron pipe, sometimes of 3 inches in size, but more usually 4 inches.

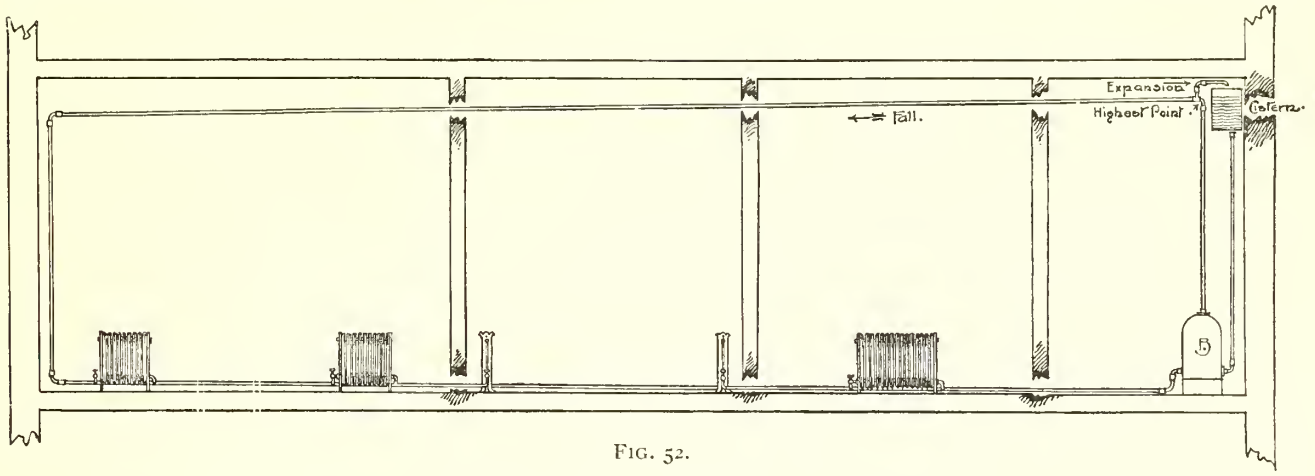


Fig. 52.

It is also the two-pipe system of work that always appears, for it would be difficult to adopt the one-pipe or overhead principle.

Although the cast pipe, as a radiating surface, is justly condemned and now quite abandoned in residence and other works carried out in good interiors, it possesses certain distinctly good features in horticultural work, and at present there is no prospect of anything else being substituted. Glass is a rapid heat loser, and if in, say, a 15 feet greenhouse a radiator was placed at one end, there are doubts if it would afford a proper warmth at the other end, and in any case there would be a marked difference in temperature. With pipes running the whole length this ill result is quite absent. Most importantly, however, the large pipe excels in its work by holding a comparatively large volume of water. It will be realised that a large bulk of water, when it has attained a given heat, will be slower in showing a change of temperature than a smaller bulk would. This means that neither careless overstoking nor neglect will cause so serious a change of temperature in the glass-house heated by large pipes as would be the case with the smaller quantity of water held by small pipes or radiators; and as undesired changes of temperature are particularly prejudicial to the horticulturist's work, he will always favour anything that prevents or reduces them. Briefly put, the large pipes, by holding a good bulk of water, are slow to heat and slow to cool, the former not being objectionable in this work, while the latter is a decidedly good feature.

One of the most useful introductions for glass-house heating is the "Loughborough" boiler and its set of pipes. This type of boiler now appears in all makers' catalogues, as being not only specially suitable for nearly all small jobs, but also being easy of erection by comparatively unskilled labour. Fig. 53 illustrates this. It will be seen that no boiler pit is required, the boiler being fixed in the thickness of the greenhouse wall at one end (either end). The back of the boiler, to which the heating pipes are connected, projects inside the house; while the front of the boiler, carrying the feeding and cleaning doors and the flue nozzle, comes outside. Thus the boiler can have all necessary attention without opening the door of the house, and the cost of fixing is greatly reduced. The heating pipes extend along the front wall inside the house and terminate in an upright box cistern. This latter appliance is ingenious as fulfilling several purposes. Without this there would require to be a siphon-end

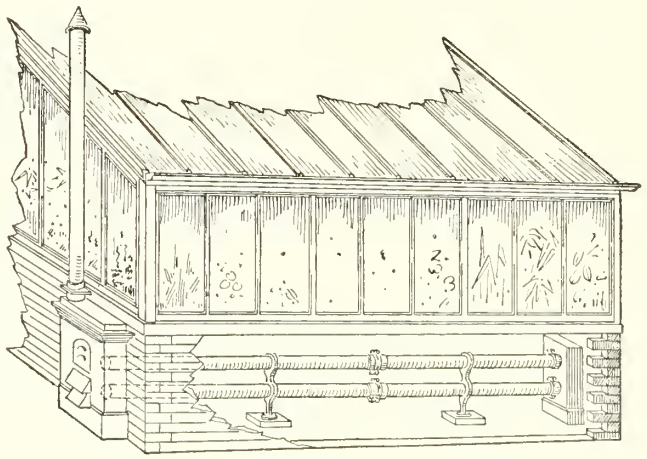


Fig. 53.

to join the pipes. This would have to be drilled and fitted with an air pipe, and then a cold-supply cistern and pipe would have to be provided and fitted. The box cistern, commonly called an expansion-box, serves all these purposes by joining the pipes, being an air vent to them (it having a loose lid), and being also a supply cistern. The joints of these complete outfits are usually of a simple kind, with a rubber ring

which is compressed by screwing up two bolts. It would be quite possible to make this apparatus heat two houses by inserting an H-piece and valve to control the circulation to the second house.

Except in heating one or two houses it cannot be hoped to get good results by running the pipes without regard to the separate regulation of the temperature of each house. There must be a pair of main pipes, with branches to each house according to its requirements, the branches having controlling valves, known as throttle valves, in them. An idea of this is given in Fig. 54.

This is an imaginary yet quite ordinary arrangement of four houses, but it should be stated here that the heating engineer never has to settle the arrangement of pipes, and not always is he required to say what quantity should be used. The gardener or grower decides such points, and his word is final. It is always arranged, when possible, that the hottest house, called a "stove," or the tropical house, come nearest to the boiler, and the average gardener considers that too much pipe cannot be put in here. The next house may be an early vinery, with a little more pipe than the next house, which is for later grapes. The last may be a "cool house" for half-hardy plants.

The mains are commonly carried through the houses as shown, but quite frequently they are carried in a range of pits (for melon growing, etc.) along the fronts of the houses, the branches going from here into the houses. Near the boiler it will be seen that the first branch is carried at a low level part of the way; this is to get it past a doorway that must exist there. All high points have air vents, air pipes being invariably used for these. These pipes must be carried with a rise at all points, as air will not escape through water in a downward direction. No parts of the air pipes which contain water may be carried outside the house.

The cold supply is arranged by placing a small cistern at any point above the line of the highest pipes, and from the cistern a supply pipe is brought down and enters the main return close to the boiler. As a rule, the cistern is placed as nearly over the boiler as possible, inside the first house. It is stated above that a small cistern is used; and this is the general practice, little thought being given to providing a cistern bearing any relation to the quantity of water in the apparatus. It has been explained that water expands to a known extent when heated, and with works inside brick buildings the cold-water cistern has to be of such a size as will accommodate the increase due to expansion. In a glass-house the gardener expects an overflow at his small cistern when first heating up, and the trouble is ended then, as the water is not allowed to cool down day or night until the warm weather comes. Expansion pipes are not always put, as a number of air pipes serve the same purpose.

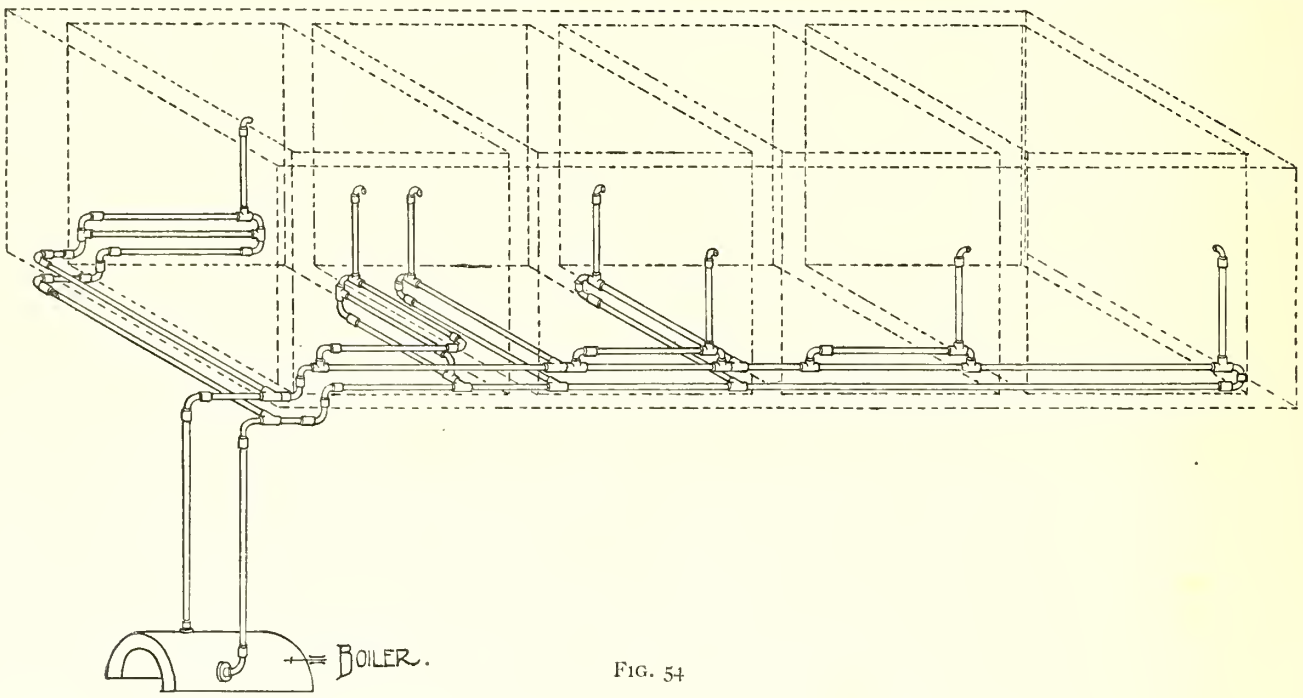


Fig. 54

The Joints used for cast-iron hot-water pipes may be said to be confined to the borings joint, red and white lead, and rubber collars. The borings joint, also known as the rust joint, is made as follows:—Mix well together in a dry state 80 to 100 parts by weight of iron borings, two parts of flour sulphur, and one part of powdered sal-ammoniac. The borings can be obtained very cheaply from factors who supply the pipe; and they should be beaten small if very coarse. Afterwards mix all with sufficient water to moisten the

whole, but not to make it very wet. This should be done an hour or two before it is required for use. In making the joint, the yarn or gaskin is cut into lengths sufficient to make about three turns round the pipe, and this is caulked in, length by length, until the socket is about three-fourths full. It may be explained that the joint, so far as keeping the water in, is made by the yarn, while the borings mixture is used only to back it up and keep the joint permanently sound. When the yarn is in the borings follow, and, while these should be caulked securely in, some care is needed, as the mixture expands a little in setting. It is this expansive action which makes the joint so firm a one, but it also cracks the pipe socket if care is not used. On this account it is best to use the least practical quantity of borings ; and while fitters have different ideas in regard to this, it will be found that a depth of three-quarters of an inch will be satisfactory. Freshly mixed borings are more liable to cause trouble than a mixture which has stood from one to two hours (according to the dryness or dampness of the weather).

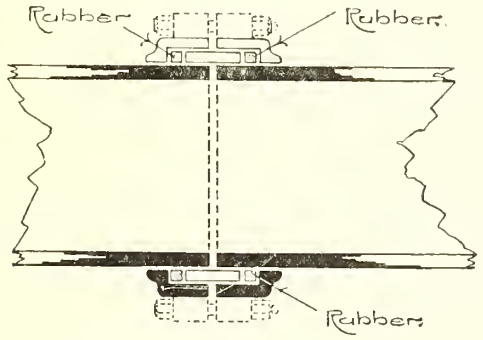


Fig. 55.

The borings joint is seldom used when the number of joints to be made is small. In this case dry red and moist white lead are resorted to, these being mixed together to the consistency of putty. A small quantity of this putty is thinned with linseed oil, to make a paint, and the inside of the socket and the outside of the spigot end of each pipe are painted with it. A length or two of yarn is first caulked in, on top of which some of the putty is put. This is followed by more yarn and putty, alternately, until the socket is full. It is a somewhat expensive joint, owing to the cost of the lead, but not sufficiently so to be objectionable with a few joints.

A joint of intermediate cost can be made by substituting the following mixture for the lead putty :— Two parts of dry slaked lime (or whitening or chalk will do), one part litharge, two parts clean sand, and sufficient boiled linseed oil to make a putty. This is used with yarn in alternate layers, as is the lead putty.

There are several patented joints in which a rubber collar is used as the jointing medium. Some of these require both ends of the pipe to be specially formed, and some have one plain end, while Jones's joint, illustrated in Fig. 55, is used with pipes and fittings having all ends plain. This latter joint does not bear much pressure, and is therefore used wholly in horticultural works or those of limited elevation. The makers consider it suitable if the head of hot water does not exceed 25 feet.

Quantities.—*Being the Area of Low-Pressure Hot-Water Heating Surface required to obtain given Temperatures in Rooms and Places.*

Brick-Built Structures.

Temperature required when it is 30° outside.	Super. Feet of radiating Surface per 1000 Cubic Feet of Space.	Purposes.
Degrees Fahr.		
50	9	Coach-houses, stores, etc.
55	12	Places of worship, places of employment, bedrooms.
60	15	Living rooms, offices.
65	18	Living rooms.
70	22	Bathrooms
80	38	Drying rooms and trade purposes.
90	66	
100	115	

Glass-Houses.

Temperature required when it is 30° outside.	Length of 4-inch Pipe per 1000 Feet of Space.	Purposes.
Degrees Fahr.		
40	22	Cool-house for half-hardy growths.
45	30	Fruit, conservatories.
50	39	
55	48	Grapes, tomatoes, cucumbers.
60	58	
65	69	
70	81	Orchids, melons.
80	110	Pines, and forcing.

In finding the surface required in brick-built structures the above table makes no allowance for a varying area of glass (windows), and as glass is a rapid loser some consideration should be given to this. Many engineers are satisfied to use a table such as that given, and then make a mental allowance as the size of the windows is seen, but others prefer a calculation such as the following :—

To obtain 60° in any ordinary brick-built room when it is 30° outside: allow 1 square foot of heating surface to each 5 square feet of glass, with the addition of 12 square feet of surface to each 1000 cubic feet of space. If the room has two exposed walls, add 10 per cent. to the above.

CHAPTER VI

HOT-WATER HEATING WORKS—HIGH PRESSURE

The High-Pressure heating apparatus takes its name from the fact that it is either hermetically sealed or is closed with a heavily loaded valve, so that a considerable pressure occurs in the pipes and parts when the water is expanded by heat. What, to many, is a peculiar result of heating water under pressure is that this liquid then reaches a temperature far above 212° (the commonly recognised boiling-point) without boiling. In the ordinary way water will boil at 212° Fahr. (or closely thereabouts according to the height of the spot above sea-level), and once boiling-point is reached the water ceases to gain in temperature, however fast the boiling may be made to occur. If, however, anything can be done to prevent the boiling, then on suitable heat being applied the temperature of the water will continue rising, and reach quite high figures. It raises a feeling of doubt as to what temperature water could be raised to by heating it under suitable conditions and in a vessel of sufficient strength, but no hesitation need be felt in saying that something like 600° has been reached in a high-pressure hot-water apparatus (by bad work or firing), while 300° to 400° is a normal heat for the water in these pipes.

The action of boiling, or ebullition, which occurs when water is sufficiently heated, is controlled by the pressure exerted on the water. In open vessels at sea-level the pressure of the atmosphere is 14.7 lbs. per square inch, and this is exerted on the water, with the result that boiling occurs at 212° Fahr. On high lands, or below the sea-level, the boiling-point is lower or higher, owing to the pressure or weight of the atmosphere varying accordingly. If, however, a vessel containing water is soundly closed, then atmospheric pressure has no influence on the boiling-point, and it can be controlled quite independently.

In Fig. 56 are given the details and outline of a small apparatus, which will serve for explanation. In the first place, it will be seen to consist wholly of pipe, this being necessary on account of the pressure that is exerted by the water. No form of boiler would stand it, therefore a coil or arrangement of tube is always used as the heater. The tube, too, is of special strength, being of $\frac{1}{4}$-inch substance, $1\frac{5}{16}$-inch external and $\frac{13}{16}$-inch internal diameter; it is generally spoken of as $\frac{7}{8}$-inch tube. To give an idea of the strains the tube is expected to bear, it is customary to test a finished apparatus to a hydraulic pressure (cold) of 1800 to 2000 lbs. to the square inch.

In the illustration it will be seen that the top tube of the furnace coil goes away as a flow-pipe, and continues unbroken by branch circuits, coming back to the lower tube of the coil, thus making the apparatus consist of one endless line of pipe except for the expansion tube. This arrangement is of importance, it being necessary for the filling and subsequent proper working of the apparatus; and all installations, however extensive, should consist of one endless pipe. In large works there may be several separate circulations, and the heater may be spoken of as a 5-pipe coil (with five flow and five return ends), yet, as will be shown directly, this may, and should, wholly consist of one single endless pipe.

It will be noticed in Fig. 56 that the flow-pipe passes but once around the first floor above the heater, and the second pipe is the tail end of the circuit after it has been twice round the second floor. This arrangement is not absolutely necessary, but is given to show how the heating may be equalised if the two floors are to be served equally well. Thus the first floor is given the hottest and coolest pipe, while the second floor has two pipes both within these two extremes, and it might be hoped by this plan that each floor would receive about the same number of heat units. As the runs of pipe often reach 500 to 600 feet it follows that, swift as the circulation may be (as it is with these high temperatures), there is a marked difference between the temperatures of the flow and return pipes where they are near the heater; consequently, in planning the runs of pipe it is proper to share out the flow and return as equally as possible in the various rooms or sections of the building. Exception to this can be made when some rooms are of greater importance than others; or, when it appears best to increase the proportion of piping in those rooms which have an unfair share of return pipe.

The filling of the apparatus is done from a low point by the "pumping valve" shown there. It is not done at the point marked "filling cap." This latter term is a misleading one, but is used in the trade; its correct name would be "replenishing cap," and its use is described a little farther on. In an apparatus such

as this it would not be easy to fill properly from the top, and it is further found that, by pumping, the pipes are well scoured and freed of air, as they need to be. Again, this kind of apparatus has air gather in it, in course of time, and only by pumping water through can this be properly removed. The engineer usually books a contract to do this repumping once yearly, at the beginning of each winter season.

There are different forms of pumping valves, some engineers having a design made for their exclusive use. These usually take the form of a four-way gun-metal valve, which can have an ordinary portable lift-and-force pump attached, and have two outlets capped off when the pumping is done. What may be termed the ordinary form of pumping valve, or pumping-through cock, which is obtainable from any factor or manufacturer of these goods, is a miniature lift-and-force pump itself. To the best of belief it is not claimed that one is better than the other, but the engineer's valve has the advantage of preventing strangers interfering with or attempting the repumping, as its use is not obvious. From the foregoing it will be seen how essential—certainly desirable—it is that the apparatus consist of an endless tube. There could not be the same certainty of the pumping removing all air from, and filling all parts of, the piping, if there were branch circulations; in fact, it takes a very skilled man to say when a branch circuit may be attempted without the risk of air being driven up to its remote end, if it has one, and being held there by the water.

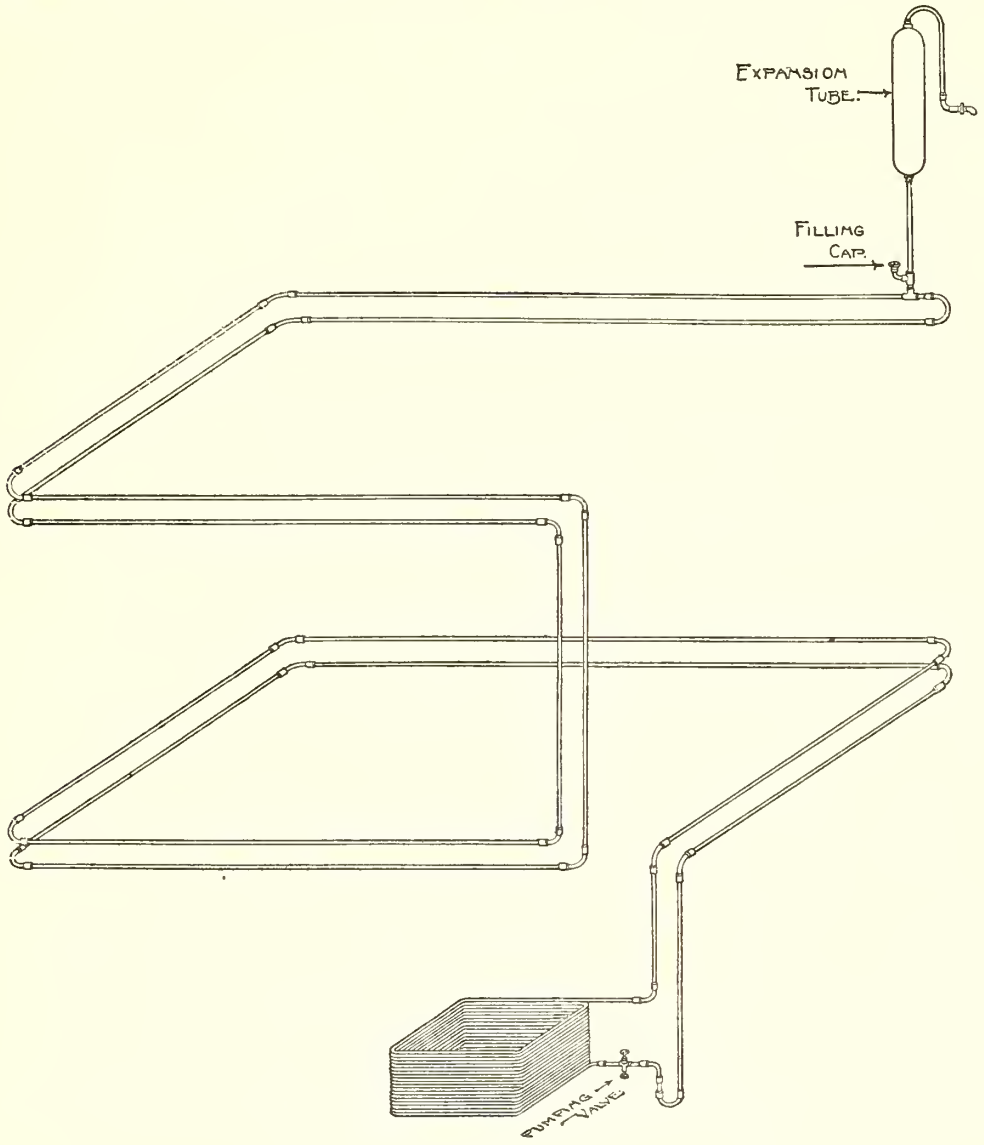


FIG. 56.

Near the extreme highest point of the apparatus the "filling cap" is situated, and the expansion tube is situated above this. The filling cap is the cap on the elbow branch shown, and it is up to this point that the apparatus is filled with water. The cap is specially made to admit of frequent removal and replacing, and

when the engineer has finished an apparatus he leaves a strong wrench with the caretaker of the building with instructions to remove this cap about once monthly and pour in any water that the pipe will accommodate. The caretaker does this, of course, when the fire is not alight, and it is peculiar that it should be necessary in an apparatus that is sealed at all other times.

Assuming that the apparatus is full of water up to the filling cap, it follows that the expansion tube is left full of air. On lighting the fire the water at once commences to expand—to increase in bulk, and, finding no way of relief anywhere else, it starts forcing its way into the expansion tube with a consequent compression of the air there. As the heating continues so does the bulk of water increase, and the air compression becomes greater, and as the compressed air must press back on the water with exactly the same force as that exerted in compressing it, it will be seen how the water is prevented boiling and the boiling-point never reached. The hotter the water becomes, the greater is the pressure exerted on it by the air, and it is difficult to see how a boiling-point can be arrived at. It might be assumed that the same result could be attained without an expansion tube, but the expansion of water is so strong a force that without a cushion-like substance such as air to exert this force upon, the apparatus would be fractured somewhere in a very brief space of time.

The description given, so far, only applies to quite small works, and although the details of filling and expansion remain the same, there have to be special features in the furnace coil when the undertaking is a large one. If $\frac{7}{8}$-inch (or 1-inch) pipe were run in this way for low-pressure heating, a circuit of about 200 lineal feet would be considered a maximum length, if the return pipe was expected to be of a useful heat. With high-pressure work the circulation is more rapid and the conditions more favourable ; therefore a length of 500 feet is allowed as having a sufficiently hot return pipe. If a circuit is of greater length than 500 feet there is a risk—a tolerable certainty, in fact—that part of the return will be of a very limited degree of usefulness, for it will be below the temperature expected of high-pressure heating surfaces.

The above being recognised, it becomes necessary in large jobs to run the piping in sections or circuits of about 500 feet each, yet this must not be done by any system of mains and branches. It is a better plan which is adopted, it being arranged that each circuit have its water come back to the furnace, to be reheated, and then go out again, and this is effected by using a heating coil consisting of two or more intercoiled pipes.

In Fig. 57 is shown a three-pipe furnace coil suited for a 1500 feet job, or thereabouts. It will be seen that this coil has three flow and three return connections, there being, in fact, three distinct coils intercoiled. What has particularly to be pointed out is that each coil must not be given a section independently. If this were done then each circuit would require its own expansion tube and other fittings, and unless they were very carefully proportioned it is probable that, while one overheated the others would be partial failures. What has to be done is to let the circuit which starts out from the flow connection of one coil come home and join the return connection of another coil ; and if Fig. 58 is studied it will be seen that, by this arrangement of connections, the whole apparatus remains one endless tube, as it should do. It will be seen that the top flow is made to communicate with the bottom return, and that each flow returns its water to a different coil to that it started from. If the pipes were followed up or straightened out they would be found to be one endless circuit of pipe as much as those in Fig. 56 are. There is no rule to follow as to which flow shall communicate

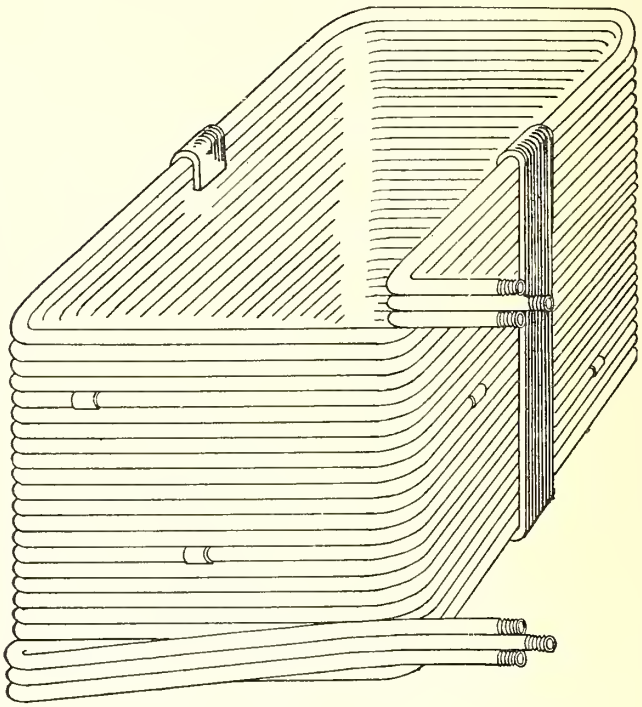


Fig. 57.

with a certain return ; but a good plan, when the circuits differ in length, is to let that which is longest come back and join the coil which has the shortest run from its flow connection. This helps to equalise the general heating.

A detail of Fig. 56 which remains to be explained is the method of jointing the pipe. The screw or thread on the tube is finer than that of ordinary hot water or steam tube, and special dies are employed for this. Each piece of pipe, and socket, has a right-hand thread at one end and a left-hand thread at the other ; so that when the two ends of pipe enter a socket, and the socket is secured up, the ends approach one another, and ultimately meet in the middle of the socket. The ends of the pipe, which meet in the socket, are finished, one quite flat and the other with an annular

chisel or coned edge, as shown in Fig. 59; and the result of screwing the socket up is to make the end of pipe with the chisel edge embed itself in the flat edge, and this, by itself, makes the joint. No jointing material whatever is used. In preparing the ends of the pipe

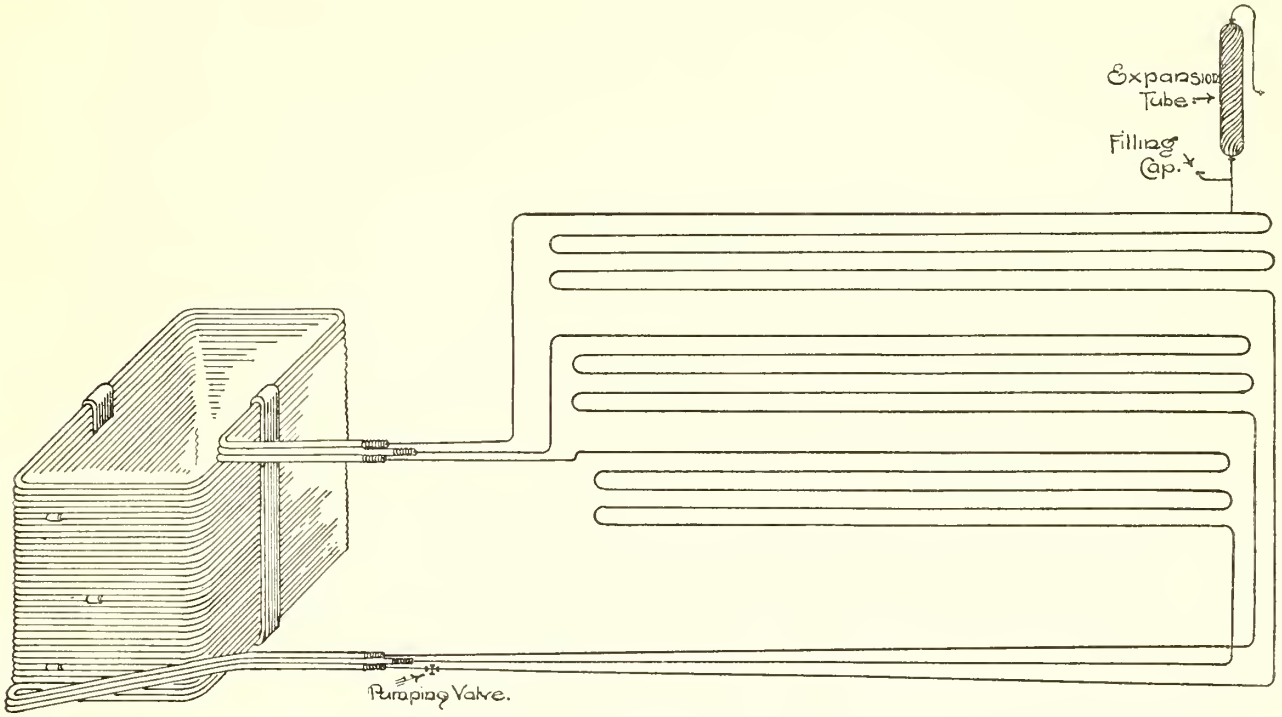


Fig. 58.

the fitter commonly relies on a file to finish the flat end, also the outside bevel of the coned end; while for the inside edge of the latter a tool like a countersink serves. Those who do the work largely sometimes have special tools for both ends, the chief object being to get the ends quite true, so that they precisely meet on coming together in the socket When the fitter relies on a file and countersink for finishing the ends he carries a

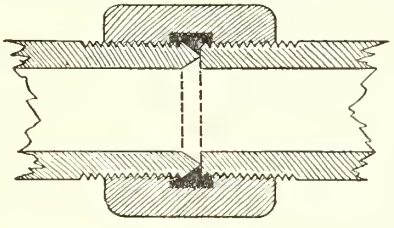


Fig. 59.

small steel square with which the ends can be tried as he proceeds with them.

The Limited Pressure is a modification of the high-pressure system, and in which the pressure — and temperature —can never rise beyond a certain desired point. This is effected by the use of a special form of combined outlet and inlet valve, fixed in the position that the expansion tube otherwise occupies. The valve is used in place of the expansion tube, and, as will be seen, the filling cap can be dispensed with. In other respects the apparatus remains the same as the high-pressure system.

Fig. 60 illustrates the details of a valve suited for this purpose; but, it may be mentioned, engineers professing this work have, in some instances, valves of their own design and make. The upper part of the valve, it will be noticed, is practically a dead-weight safety valve—a valve which opens and provides an outlet when

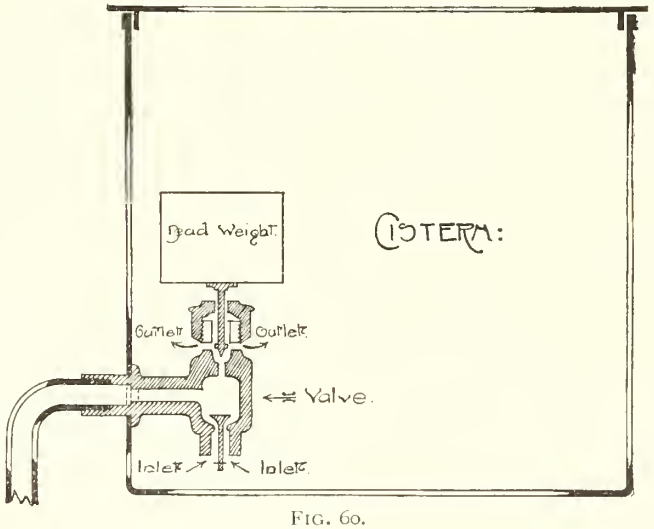


Fig. 60.

sufficient pressure is exerted from the inside. The lower part of the appliance resembles a spindle valve, which closes and holds tight when pressure is exerted upon its head, but opens easily to pressure from beneath

the head, no weight or spring being needed to control the operation of this.

Assuming the apparatus is ready for use and the fire just lighted, the water at once commences to expand. The apparatus being wholly full of water, there is no space for the water to expand into, and consequently it lifts the upper spindle of the valve in the cistern and discharges a certain quantity of water there. Before the discharge, however, the pressure within the pipes must be sufficient to lift the load on the valve spindle, and this being set (usually) to open at 70 lbs. to the square inch, it follows that the pressure the water is under before the valve opens admits of a high temperature being obtained. A pressure of 70 lbs. to the square inch admits of the water reaching a temperature of 316° Fahr.; and this, or a figure near it, is considered as high as the apparatus should be worked at, whether it has a valve or an expansion tube upon it. Occasionally an engineer may say that 350°, requiring a pressure of 120 per square inch, is best, but, unless the idea is to get the rooms warm with the least quantity of pipe, the rule is to work at a lower pressure and temperature.

Supposing, therefore, that the water has reached, say, 316°, with its accompanying pressure of 70 lbs., and the outlet part of the valve is ejecting water, it follows that, sooner or later, the temperature of the water will fall a little, and then, with the accompanying contraction of the water, a vacant space—a vacuum—must occur, or be about to occur, in the apparatus. This is prevented, however, by the immediate opening of the inlet valve; for directly a state of vacuum is experienced inside the apparatus the inlet spindle is lifted, and water carried in, by the pressure of the atmosphere. Thus, at times, the valve is first ejecting, then drawing in water, quite frequently, as the temperature of the apparatus varies. Almost needless to say, the lower part of the valve at least must always be beneath water, and there is no objection to the whole being submerged.

A pressure gauge is a very desirable adjunct to a high-pressure apparatus of any kind, this being fixed in the stoke-hole, in sight of the stoker, as by indicating pressure it becomes, in a sense, a temperature indicator. A very little practice then enables the stoker to regulate the heat of the water according to the weather, and he can by this means soon obtain a correct warmth in the place to be heated by merely consulting an outdoor thermometer and then working to the figures on the gauge.

Quantities relating to the High-Pressure System of Hot-Water Heating Apparatus.

Temperature required when it is 30° outside.	Length of $\frac{7}{8}$-inch Pipe to be allowed to each 1000 Cubic Feet of Space.	Length of Pipe to form Furnace Coil.	Size of Expansion Tube.
Degrees Fahr.	Feet.		
50	15	$\frac{1}{12}$ the length of the radiating pipe.	$\frac{1}{9}$ the size of the whole of the other pipe.
55	19	$\frac{1}{10}$ ditto.	$\frac{1}{8}$ ditto.
60	24		
65	28		
70	34		

CHAPTER VII

STEAM-HEATING APPARATUS

Before describing the different "systems," or methods of carrying out steam-heating works it is necessary that some particulars be given as to the generation of steam and its action when generated. In the first place, the heating engineer must entertain no idea that the piping of steam works has any relationship to that of a hot-water apparatus. Both may consist of lines of pipes, and in most cases there has to be a kind of circulation (of steam) established ; but beyond this, to associate hot-water practices with those of steam work must only end in confusion and failure. This is mentioned as the idea that the two bear a resemblance to each other is not a rare one.

With many—the inexperienced—there prevails an impression that steam heating is very simple, owing to the fact that steam can be made to readily pass through pipes, and in this respect the impression may be a correct one. With any method of heating by steam, however, there are two difficulties to be overcome, and it might almost be said that the skill required by the engineer lies in dealing with these. One, the chief one, lies in disposing of the condensed water ; the other in defeating the ill effects that air in the apparatus can produce. In affording heat by steam the chief result, other than obtaining heat, is the condensation of the steam into water ; for only by this means can the heat-distributing surfaces—pipes or radiators—in any modern form of apparatus be kept supplied with new steam. A radiator, for instance, when doing its work is perpetually losing heat, with a consequent return to water of some of the steam within it. This causes a state of vacuum (partial) to occur, which is as quickly filled by new steam flowing in. It is a comparatively easy matter to get this action of steam supply to occur, but before it will happen all air must be driven out of the apparatus, and the resulting condensed water must not only be disposed of, but it must be prevented from interfering with the steam supply.

Another natural phenomenon that the steam-heating engineer relies on is the fact that water has its volume increased 1640 times (varying somewhat according to pressure) when converted to steam. This enables him to fill an extensive system of pipes, etc., with steam without causing a serious drop of the water-line in his boiler.

Still another natural and highly important phenomenon is the latent heat of steam. The term "latent," meaning hidden, is a correct one, for although a pound of water at 212° will still register a temperature of 212° when converted to steam, it will have taken up no less than 966 units of heat in the change. It only takes 212 units to heat a pound of water from 0° (theoretically) to 212°, so that when this weight of water is converted to steam it has absorbed sufficient heat to raise about five times its weight from, say, freezing to boiling. In other words, a pound of steam, at 212°, carries 966 units, plus 212 which it received as water to reach boiling-point, making together a total of 1178 units. Of these, as will be understood, it has 966 to give out from the heat-distributing radiators, or pipes, before it assumes the form of water again.

As already stated, the condensed water can give considerable trouble if it is not properly disposed of, either by retarding the flow of steam, blocking the steam from its work, or coming in conflict with it. On this account the covering of steam mains to prevent loss of heat—chiefly to prevent the occurrence of water in them—is very important ; and it is desirable also from the fact that cooled steam means steam and heat completely lost. With hot water mains a little loss of heat, wasteful as it may be, may scarcely show at the radiators, but with steam it means the disappearance of a certain proportion of the heating power.

Although, for the purpose of explanation, the heat of boiling water has been given at 212°, as being its easily recognised temperature, this is seldom, if ever, the precise heat that the water and steam have in these works. Low-pressure steam generally registers 3 to 5 lbs. on the gauge, and these pressures would be accompanied by temperatures of from 222° to 227°. These latter figures would be accompanied by 958 and 954 as the number of units of latent heat, but the variation from the number accompanying 212° is so small as to be negligible in affording an explanation.

A remaining detail that may be mentioned here relates to the practical use of the steam in the apparatus. When a radiator, or coil of pipes, is connected on the one-pipe system, the branch, as will be learned directly, is a single pipe, and this has the customary stop valve where it joins the radiator. With the two-pipe system each radiator has a pair of branch pipes and each pipe

has a stop valve, so that every radiator with this system has a valve at each end. The reason for thus putting two valves—and the same reason applies with the single valve in the one-pipe branch—is that when it is required to shut off steam from a radiator it must be completely cut off and leave no communication with the apparatus whatever. If, for instance, the steam supply branch were closed and the condense return left open, then steam would back up this return if it could, failing which water would be carried up and cause much trouble.

Another peculiarity related to the valves is that, whether the system be one-pipe or two-pipe, the valves at the radiators cannot be regulated; that is, they cannot be made to control the supply of steam and the heat of the radiator. Valves in this work have to be fully open or tightly closed, and this presents what is a fault in certain cases, in that the temperature of a room cannot be regulated with anything like the degree of nicety that is possible with hot water. This difficulty is aggravated by there being such a small possible range of temperature in the steam itself. If the working pressure is 3 lbs., then, however the fire is tended, only a variation of about ten degrees can be had in the steam, whereas in hot water it is customary to let its heat be from 120° to 190°, a variation of 70°, according to the weather. This difficulty may appear to be greater than it really is, for in large interiors, and most of the places where steam heat is employed, a sufficient regulation of temperature is easily obtained by closing or opening the valves of a certain number of radiators. This would not be possible in a room heated by a single radiator, but in places where each room or space has several radiators or coils of pipe one or more can be shut off independently.

The reason that steam radiator valves cannot be partially opened or closed is this. Taking first a one-pipe connection, this, as stated, is a single-pipe branch with a valve at the radiator. Through this pipe and valve steam has to pass to the radiator in one direction, while the water of condensation has come back through them the other way. These two contrary movements will readily come into conflict, with bad results, if they are allowed to, and it is only prevented by having the pipe and valve of a recognised sufficient size. Thus if a $1\frac{1}{4}$-inch pipe is considered correct, then the valve must be $1\frac{1}{4}$ inch also, and it must have a clear open way through it of this size. If the valve is partially closed, with the idea of regulating the steam supply and the heat of the radiator, all the conditions of using too small a valve are immediately obtained. On this account the valve must always be wide open or tightly closed.

With a radiator connected on the two-pipe system, having a branch at each end, as the valve at the steam supply end of the radiator conveys steam only, it might be thought that its regulation was quite possible, there being no direct troubles associated with controlling the flow of steam through a pipe. No return water comes back through this valve, the one at the other end being provided expressly to convey this away. It will be found, however, that on partially closing the steam supply valve the balance of pressure between the two branches will be disturbed, and the result will be a rise of water up the return branch. This, it might be thought, could be overcome by regulating the return valve to the same extent as the steam valve, but it is not possible to do so with sufficient exactness. A twin valve has been made to be operated by one handle, so that, it would be thought, the opening or closing could not fail to be equal in both valves, but this did not act so successfully as was anticipated.

To the best of belief, this difficulty with the valves, the inability to regulate them, has never been overcome in English practice, but quite recently a system of work practised in France and Belgium, in which valve and temperature regulation is all that could be wished for, has become known in this country, and there is considerable prospect of its gaining ground. This system will be found described a little farther on.

Description of Low-Pressure Steam-Heating Works which return the Condense Water to the Boiler, known as Gravity Systems

In modern English and American practice the steam mains are always arranged as a circuit—as a flow and return, it might be said; so that the condense water from radiators and pipes flow naturally, by gravity, back to the boiler. This is a detail that has greatly advanced the use of steam as a heating agent, as, by having a constant water-line in the boiler, a skilled attendant can be dispensed with. This desirable result has been perfected, too, by the introduction of the automatic damper regulator, as this automatically controls combustion, generation of steam, and steam pressure. This will be found explained later.

When steam heating was first seriously attempted the practice was to run all pipes singly and with a rise up from the boiler, so that the steam passed to its work and the water of condensation trickled back within the same pipe at all points. This was a true one-pipe system, but it was soon found to be of great advantage to have *the steam and condensed water travel together in the same direction*, as far as possible, lessening the risk of their coming into conflict while, with their contents flowing agreeably together, admitting of smaller pipes being used.

In all works it is now the rule to arrange that the steam and water travel in the same direction, whenever possible, as otherwise there is some risk of poor results, and it is then always necessary to use larger pipes.

The One-pipe System

Fig. 61 illustrates the general details entering into an apparatus on this system. In the first place, it will

be seen that the installation is practically sealed at all points. This is to prevent loss of steam, which would mean loss of heat and fuel; also loss of water, which would spoil the best feature of the gravity system, its constant water-line in the boiler. The apparatus being sealed, however, causes it to come under the heading of a rather vexatious rule in the London Building Act, it being required that a steam installation without a "free blow-off" shall have its pipes and parts kept 6 inches from inflammable material. It is awkward, yet in the majority of places where steam heat is used it does not usually prove a very difficult rule to adhere to. The rule is vexatious because a low-pressure hot-water apparatus, which often has its pipes (near the boiler) hotter than low-pressure steam pipes, is free of all restrictions, while a high-pressure hot-water apparatus, with its water at 300° to 400°, need, under this rule, be kept only 3 inches from woodwork.

The main, which in this work is called the steam-supply main, it will be observed, makes a circuit wholly above water-line; and, to get the steam and condense water to travel together in the same direction, the main is always carried to its highest point as near over the boiler, that is, as quickly as possible, and then run with a fall all the way out and back again. This is a rule always observed.

The branches, it will be seen, depart from the desirable plan of getting the steam and water to travel the same way within them, as it is impossible to

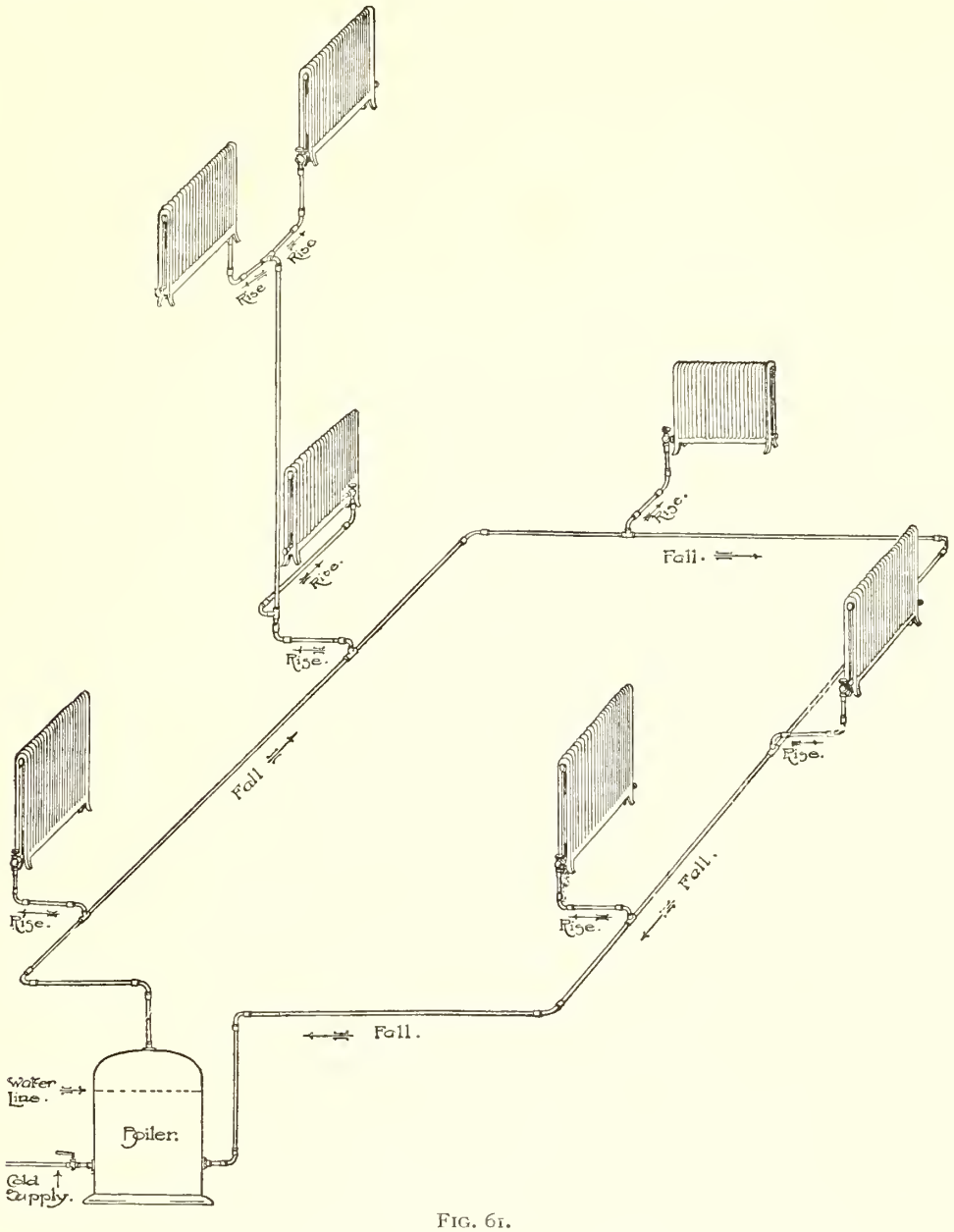


FIG. 61.

obtain this result in a single-pipe branch. The trouble, however, is not so great a one in branches as in mains, and it is overcome by using pipe of sufficient size to prevent the steam and water coming into conflict. All branches are connected by tees looking upwards, and are given a rise from this point. The minimum fall in mains is 1 inch in 20 feet, but these figures do not apply to the rise given to branches, in which the fall of water is retarded by the flow of steam. The rise must be at least 1 inch in 3 feet, and always more if possible. In America they have a fitting for this work called a "pitch elbow," which is very useful, as it is not easy to get a sharp rise with an ordinary elbow or bend.

As with hot-water work, the radiator branches must be made to "swing" to any movement of expansion or contraction in the mains. This provision is, in fact, more necessary with steam, as the range of temperature (from cold to 3 lbs. steam) is greater, and it occurs with comparative suddenness. The connection is made like that on the flow-pipe of a low-pressure hot-water system, and its general appearance can be judged from Fig. 61. The main, in order to provide this swing, is never run immediately beneath the radiators, but should it come so in one or more cases, then the swing connection is obtained by taking the branch to the distant end of the radiator, as is shown with the radiator at the foot of the branch which goes to a higher floor (see Fig. 61). To reach radiators on a second floor above the boiler, a branch can be carried up, but this is then known as a "riser." Risers can be taken to any height and carry any number of radiators, but, as will be shown, a riser which has much water coming down it is best drained or "dripped" into a separate main return.

To those inexperienced in this work it may seem possible, on examining such a sketch as Fig. 61, to have two branches to each radiator and so get over the difficulty of using one branch to carry both steam and water. The first branch might carry steam, it is thought, while the second branch could be made to deliver the water to the main. This does not work out correctly in practice, however, owing to the simple fact that, the steam pressure being equal where both branches leave the main, the steam would try to flow up both. One would quite defeat the other, leaving the radiator badly served.

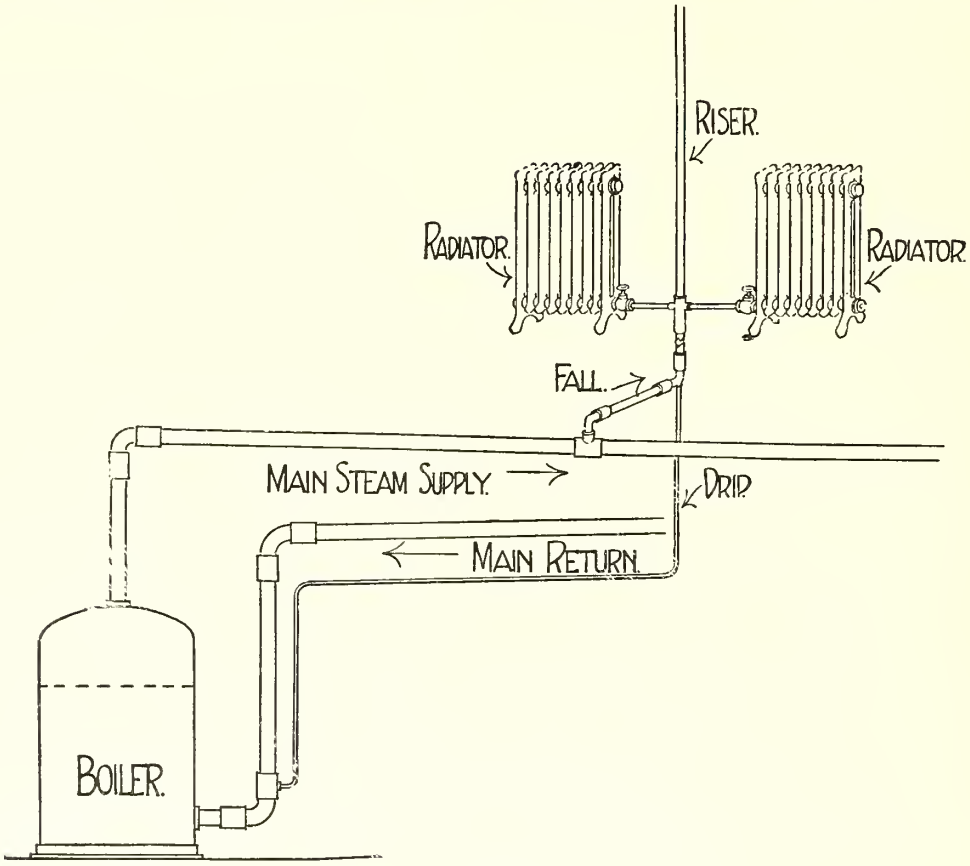


FIG. 62.

When risers have a large area of radiation on them, and consequently deliver a fair volume of condense water at their lower ends, it is desirable that they be "dripped,"as it is called, if this is in any way possible. If only one riser needs so treating, its "drip" can be arranged as shown in Fig. 62, this return being an overhead pipe until it descends and joins the return of

the main circuit. (It may be noted here that there are no objections to returns joining one another in this work, as there is with hot-water circuits, provided that they join below water-line.) If, however, several risers are dripped, or there are other drips to be dealt with, then they must either all return separately to join the main return below water-line or they can be given a "wet" or submerged return of their own, as in Fig. 63. The term "wet" or "submerged" return occurs frequently in dealing with steam-heating works, and it refers to a return which is run below the water-line of the boiler, and is consequently always full of water. Its purpose is to water-seal the lower ends of drips, or other pipes taking the functions of returns, so that steam shall not pass up them and occasion troublesome results by approaching radiators from wrong directions. If two or more drips were to join an overhead or "dry" return, steam would probably work down one and find its way up the others, needless to say with ill results.

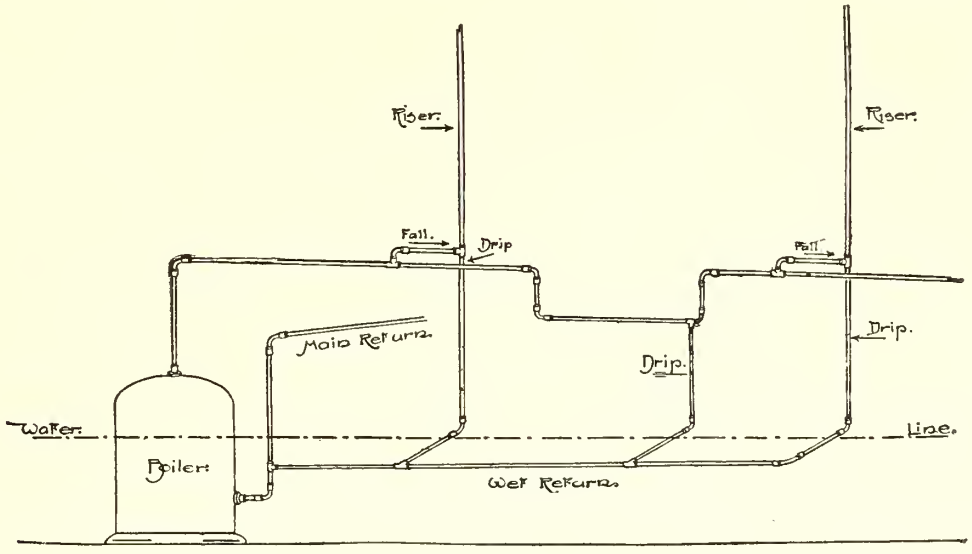


Fig. 63.

In Fig. 63 it will be noticed that the risers, as soon as they leave the main, are given a fall to their drip connections. This is the best plan to adopt, as it quite prevents any water getting into the main from the riser. It is an even better plan, when a riser is to be dripped, to make the connections as shown in Fig. 64. In adopting this plan the tee in the supply main has its outlet looking downwards.

In the illustration (Fig. 63) there will be seen a dip in the supply main, presumably to pass an obstacle. There is no objection to this, except that it forms a pocket for condensation water, but this can be disposed of by a drip as shown. Sometimes a flow main extends so far that, in giving it a proper fall, it comes too low to, say, pass over the head of a doorway. In this case the main can be carried up vertically a little way—"jumped-up," as it is expressed, before it continues its run, provided its low point is dripped.

The valves shown on Fig. 61 are all of the angle kind, and it is a good plan to use these when possible, as the condensed water drains through them easily and they have a way, or bore, equal in area to that of the pipe which they are connected to. If straight valves have to be used, then the ordinary design of screw-

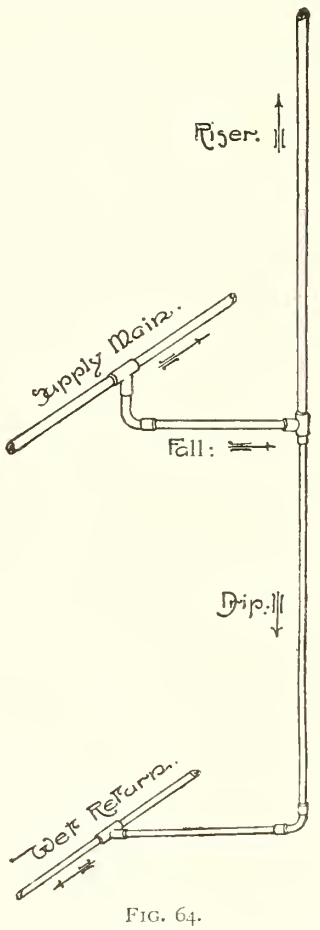


Fig. 64.

down or globe valve should be avoided, for it has an up-and-down way through it, and, at the best, this way seldom exceeds in area one-half that of the pipe. It is argued that the up-and-down passage through the body of the valve can be made a level way by fixing the valve on its side, but this does not give it a full bore. Straight valves should only be of the gate or Peet's pattern, which has a full-sized straight opening through it, like a continuation of the pipe it is attached to.

The final detail to be explained, concerning Fig. 61, is that of the air vents on the radiators. Before steam can fill a radiator the air must be driven out, and although steam at low pressure (this pressure being above that of the atmosphere) will do this, it is not so effectively done as with radiators which are filled with water. Apart from the question of pressure, steam and air are somewhat akin in weight or gravity, and consequently they are inclined to mix instead of keeping separate as air and water do. Air is the heavier of the two, and it would be assumed from this that the air vents would do best at the bottoms of the radiators, but for general purposes the best position is found to be about one-third the way up the

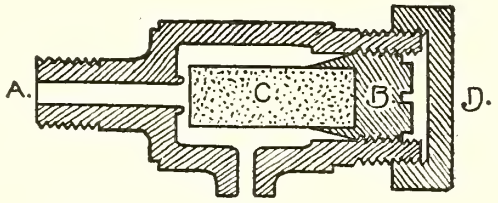


Fig. 65.

radiator from the bottom, and at the end farthest from the steam connection. If the steam entered the top of the radiator, then the bottom might be the best position for the air vent, but as the steam usually enters close to the bottom, radiators are always tapped in the higher position for the vent.

Air pipes are, of course, quite out of the question for this work, while air cocks would prove troublesome by having to be opened almost daily. The automatic air vent is always used, this being commonly called an "aspirator," as it has air passing both out and into it. When heating up the air escapes by it; then, when cooling, it opens and allows air to enter. Fig. 65 illustrates, in section, an ordinary type of this vent, the description being as follows:—A is the end which is screwed into and through which the air leaves the radiator. B is a screw plug, inside the fitting, which carries the "pencil" C. The cap D is merely to prevent B being interfered with once it is set. The pencil C is of a composition which expands rapidly with heat, and contracts as rapidly when the heat goes down, and by its expansion it closes the end of the passage A. To set these vents the radiators are first heated up, and then the plug B is screwed down until the pencil C, which is hot and expanded, just closes the opening A. It then follows that on steam going down the pencil will contract and open the vent, and so operate automatically in opening and closing. This is considered to be a reliable type of vent, and there are many modifications of it. With some a small cup can be attached to receive any drips of water that may appear.

Sizes of Main Pipes (with suitable Fall) for the One-pipe System of Low-Pressure Steam-Heating Apparatus.

Size of Pipe.	Will serve this Area of Radiation.
1½ inch	up to 200 sq. feet.
2 inches	,, 400 ,,
2½ ,,	,, 650 ,,
3 ,,	,, 900 ,,
3½ ,,	,, 1250 ,,
4 ,,	,, 1600 ,,

A common rule for finding the radiation which a main pipe will carry in this work is to square the size of the pipe and call the result hundreds. Thus $3+3=900$.

Sizes of Risers and Radiator Branches which rise from the Mains.

Size of Pipe.	Will serve this Area of Radiation.
1 inch	up to 25 sq. feet.
1¼ ,,	,, 60 ,,
1½ ,,	,, 100 ,,
2 inches	,, 160 ,,

The Two-pipe System

The one special object aimed at with the two-pipe system of steam-heating apparatus is to provide separate pipes for the steam and the condensed water, and so to arrange these pipes that the steam and its water shall naturally seek and keep to their respective channels. There is much difference of opinion as to the advantages—or otherwise—of the one-pipe and two-pipe work; but in America, which might be called the home of steam heating, the one-pipe system is favoured, though both are used. The conditions of the job often influence the choice.

Fig. 66 illustrates an apparatus which embodies all the usual details customarily appearing in these works. The steam main, it will be seen, like that of the one-pipe system, is made to reach its highest point as quickly as possible on leaving the boiler, and from here it falls in the direction of its work. This, as already explained, is to cause the steam and condensed water to travel in the same direction, and not come in conflict. It should be stated, however, that with this system the steam main is practically dry compared with that of the one-pipe system.

Branches (steam) to radiators are usually carried with a rise, and therefore any water appearing in them comes back in a contrary direction to the steam; but

the quantity is trifling, as the water produced in the radiators does not return by this route. The radiators are tilted up slightly at the steam-supply end, if necessary, to cause the water to flow towards the return connection. With branches extending up to radiators on two or more floors—and called "risers"—the foot of the vertical pipe is usually dripped, as shown on the right side of the illustration, this drip and the return from the near end. This obviates all risk of injury by the strains due to expansion and contraction of the main. On the right side of the illustration will be seen a distinctive feature of this system—which is its fault. This is the great number of return pipes that may be necessary. To carry out this work as it should be done, every radiator must have a distinct and separate return pipe down to a point below

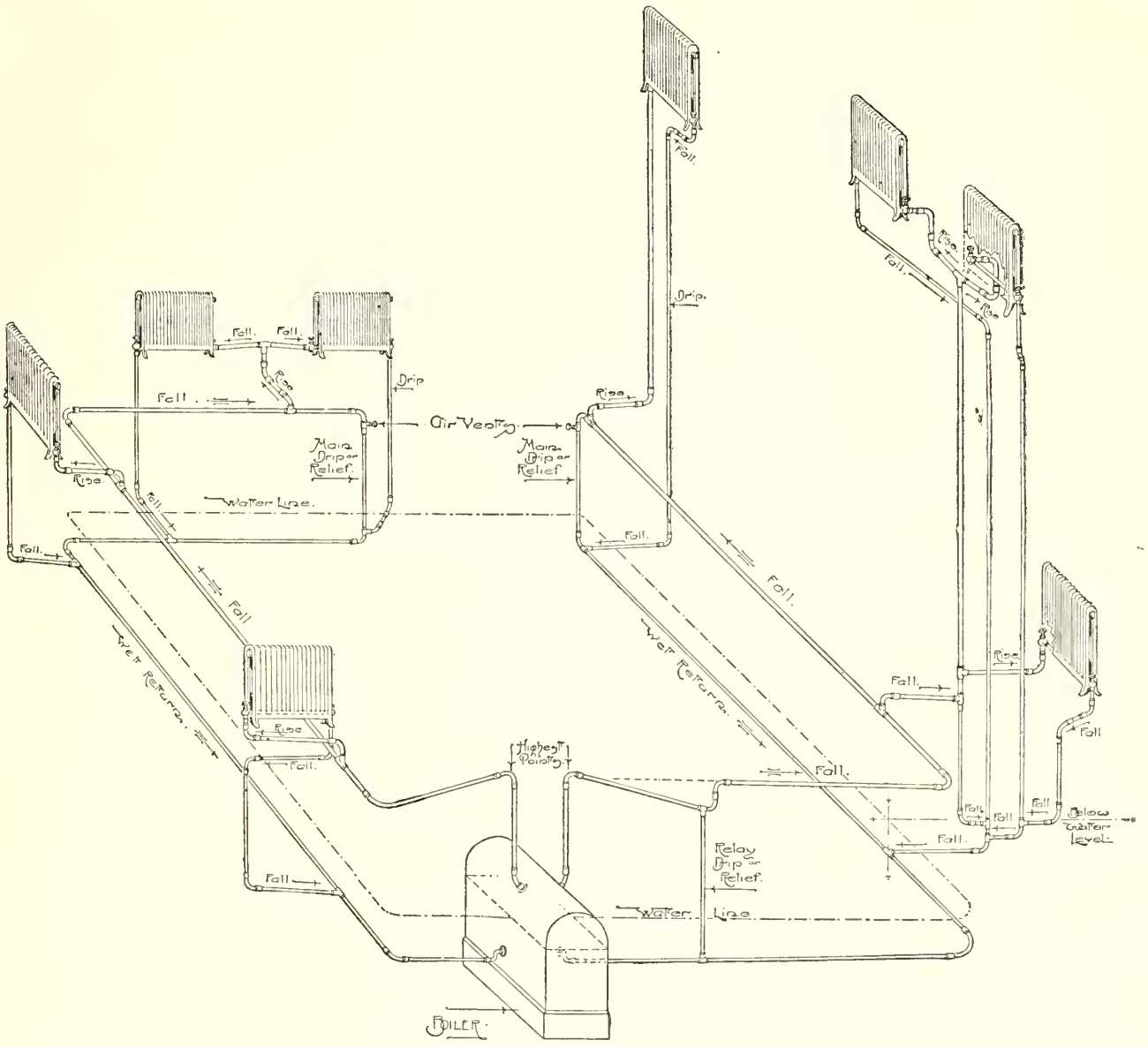


Fig. 66.

taking any water that may come down the riser and so keeping the main free. In this case the branch from the main is given a fall as shown, and in some instances it is taken with a tee looking downwards. On the left side of the illustration the first radiator is supposed to come over the main, and as straight vertical branches are not allowed in this work the steam supply is taken to the distant end of the radiator water-line. It may there join any water-sealed pipe, but may not join above water-line.

The main return is carried wholly below water-line, and is connected to the steam main by a small drip or relief pipe at the extremity of the run. This pipe should have an air vent in it above water line. This return is known as a "wet" or "submerged" return, owing to its being below water-line and always contain-

ing water. Its use is to receive the water of the return branches, but particularly to water-seal these pipes and prevent steam getting from one return to another. It needs no rise or fall, but can lie on the floor or be carried below floor line.

In the front of the illustration there appears a "relay drip or relief." As explained previously, a steam main may be run so far that its gradual fall brings it too low to, say, pass over a doorway. It may then be jumped-up, which rise is known as a relay; but the low point must, of course, be dripped. The illustration shows this, the drip joining the wet return.

Sizes of Main Pipes for the Two-pipe System of Low-Pressure Steam-Heating Apparatus.

Size of Steam Supply.	Size of Return.	Will serve this Area of Radiation
Inches.	Inches.	Square Feet.
1	$\frac{3}{4}$	140
$1\frac{1}{4}$	1	200
$1\frac{1}{2}$	$1\frac{1}{4}$	300
2	$1\frac{1}{2}$	500
$2\frac{1}{2}$	2	800
3	$2\frac{1}{2}$	1200
$3\frac{1}{2}$	$2\frac{1}{2}$	1800
4	3	2500

Sizes of Radiator Branches and Connections.

Size of Steam Supply.	Size of Return.	Will serve this Area of Radiation.
Inch.	Inch.	Square Feet.
1	$\frac{3}{4}$	48
$1\frac{1}{4}$	1	96
$1\frac{1}{2}$	$1\frac{1}{4}$	150

If the returns bore the same porportion to the steam-supply pipes that the condensed water bears to the steam they would be exceedingly small. In practice nothing like such a proportion will do, and the customary practice is to use one less size of pipe for the returns. Some engineers use two sizes less, and say that the results are satisfactory, but it is not the general practice.

The Drop or Overhead System

The Drop System may be described as a one-pipe with vertical mains, as will be seen by Fig. 67. In this, as with the overhead hot-water system, the supply main is carried up the building to the highest floor that is to be heated, and this main has no work upon it. It should always be covered to prevent loss of heat, and it requires a drip pipe at its foot as shown. At the highest point the branch or sub-mains fall in the direction of the work, and are there branched into what are commonly termed "drop risers," these being the vertical services having the radiators on them.

On the right is shown a service which has a dry return except just where it enters the boiler, and no other is needed here; while on the left a wet return is given, the object of this being to enable the returns to join without both coming all the way back to the boiler. As with all steam works, for best results the returns must not join above water-line.

The radiators are connected with the same care as is necessary with the one-pipe system, it being essential that the branches swing or give to the push and pull of the mains as they expand and contract.

The sizes of mains and radiator branches are the same as those given in connection with the one-pipe system.

The Cold Supply to all low-pressure steam-heating systems is by means of a plain pipe, $\frac{1}{2}$ to $\frac{3}{4}$ inch, taken from a main or a house service, and connected directly into the boiler, with a stop cock to control it. With modern gravity installations the condensed water flows back to the boiler, and it might be considered that, once the apparatus was filled and started, no further water would be needed. It is found, however, that there is a trifling waste from air vents and other causes, and the water-line may require elevating an inch now and again (once a week or longer). To do this the stop cock is opened, and, being near the boiler, the water gauge can be watched so that on the water reaching its normal level the cock is closed and the process ended. This could be done when steam was on if the water pressure exceeded the steam pressure (as it must do in most cases), but it is better to choose a moment when the fire is out or very low.

The Automatic Regulating Device referred to earlier, which has done so much to make steam heat possible where the attention is that of unskilled persons, is illustrated in section by Fig. 68. This appliance is connected either directly with the boiler, or with a steam service over the boiler, by a single pipe. It requires no second pipe to secure a circulation. Assuming that the steam comes up the lower pipe, it will fill the lower half of the body of the fitting, and press upwards against the diaphragm which divides the body into two halves horizontally. This diaphragm is of rubber, and the effect of the pressure beneath is to raise the central part and lift the plate and the rod which rests upon it. This action causes one end of the long top lever to be raised and the other to be depressed, and this up-and-down motion is utilised to work two specially prepared dampers, or draught controllers, by the chains shown. In most of the modern boilers there is a balanced door to the front of the ash pit, called the "draught damper," and a balanced door in the smoke nozzle at the rear, called the "check damper." The opening of the

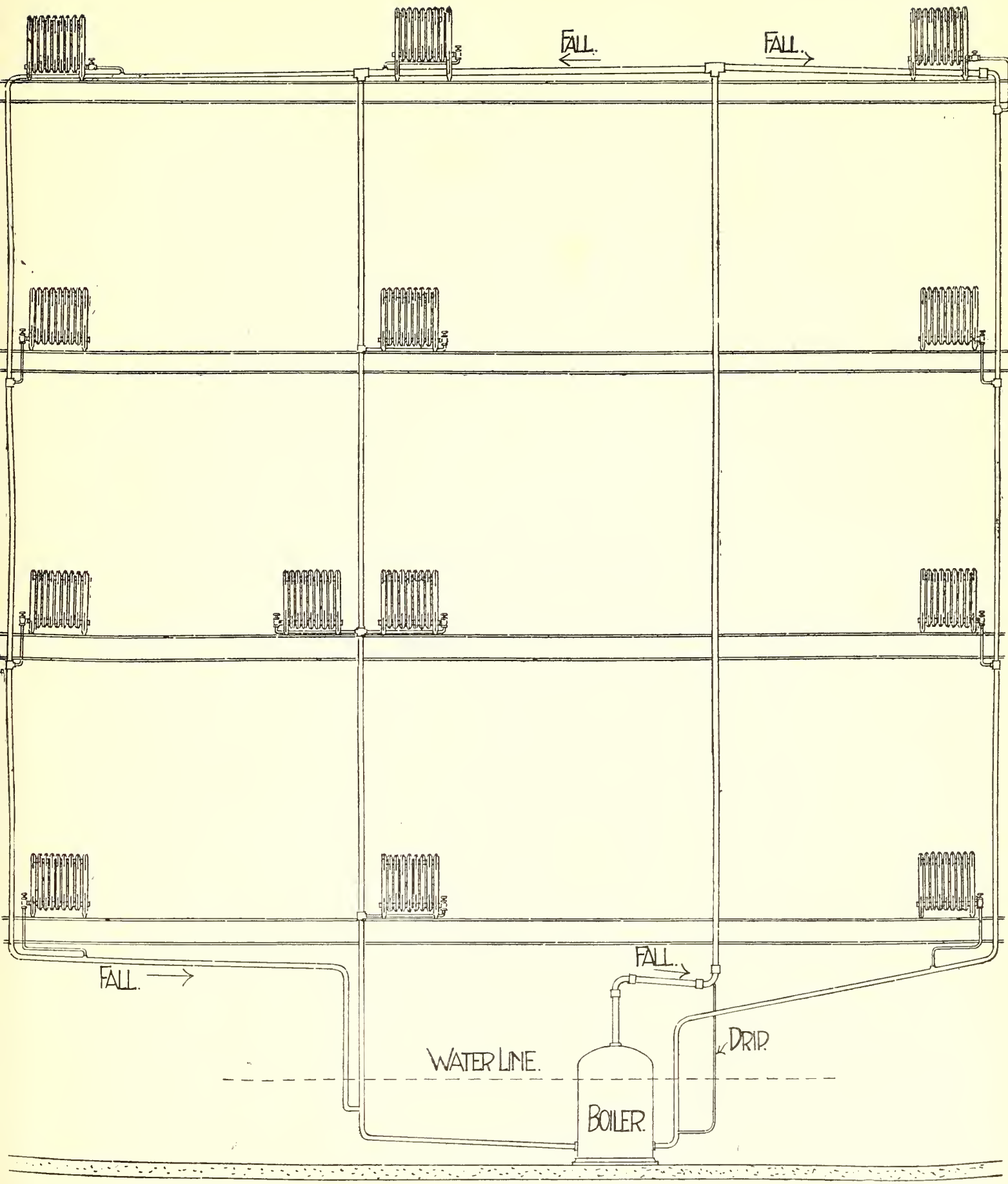


FIG. 67.

former increases the draught and combustion, while the opening of the latter checks them. The steam pressure in the appliance, and the lift it gives to the weighted end of the lever, is made to open the check damper when a certain steam pressure is reached, this at the same time closing the draught damper and checking the fire. In other words, when steam is being made a little fast its increasing pressure at once operates in checking the fire. On the other hand, as the pressure falls so does the weighted end of the lever fall also, and this brings about a reverse process. The result is that the fire then brightens up and recovers from the check. The actual effect of the regulator is to keep the fire in a condition which makes just the volume and pressure of steam required, and thus it regulates steam pressure, steam production, and combustion. It only requires the attendant to put fuel

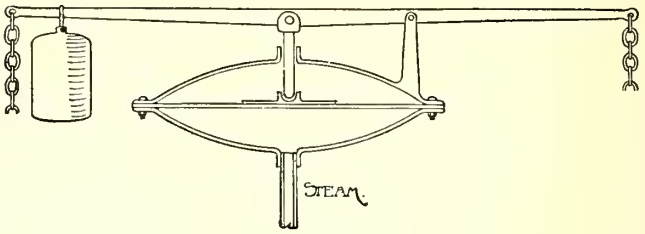


FIG. 68.

into the furnace, and the regulator attends to the dampers and keeps the pointer on the gauge at a normal figure.

CHAPTER VIII

VENTILATION: WITH WHICH IS INCLUDED WARMING BUILDINGS BY HEATED AIR

While it would be possible to treat the subject of Ventilation alone, it would not be feasible to attempt dealing with Warming Buildings by Heated Air without going somewhat deeply into ventilation. Consequently the two are included in this chapter. This will not be found to cause any confusion, and it will prevent much repetition, as would occur were the subjects dealt with separately. Remembering, too, that the Plenum System of ventilation usually provides for ventilation and warmth in winter and ventilation alone in summer, it will be seen how closely associated the two are.

The extent to which ventilation is required is determined by the extent to which the air is vitiated. It is not the deprivation of oxygen with which the air of rooms suffers that is considered, so much as the addition of impurities. Oxygen is needed, of course, but before this valuable element is used up to a serious extent the air requires changing for the purpose of removing the undesirable elements that are produced in various ways. Some authorities, quite good ones, consider the sense of smell, if the nose be normally keen, sufficient to tell if the air is pure enough or otherwise; for though ventilation is provided to remove an odourless product of respiration and combustion—carbonic acid gas (carbonic dioxide, bearing the symbol CO_2)—this is so regularly accompanied by an odour of vitiation (in occupied places) that the latter is considered to be a good index to the presence and volume of the former. In a paper communicated to the Royal Society an eminent authority, a doctor of science and medicine, went to considerable lengths to show this, he conducting his own experiments and subsequent analysis of the air. His figures may be summarised as follow:—

Odour in the Air.	Temperature.	Humidity over that of outer Air.	Carbonic Acid Gas per 10,000 Volumes of Air.	
			In Room.	Outer Air.
None (quite fresh)	63°F.	About normal.	6	4
Slight smell	63°	,,	8	4
Disagreeable smell	64°	,,	10	3·7
Offensive smell and very close	65°	,,	12.2	4

From this it will be seen that the increase in carbonic acid gas bore a very distinct relation to the smell in the air. To judge by smell, however, it is necessary to be at least fifteen minutes in the outer air before entering the room; and, as will be understood, judgment by smell is not resorted to if means for analysis are available, or if it appears to be necessary.

The analysis of the atmosphere, to a precisely accurate extent, is not usually undertaken by the engineer himself, but it is possible to ascertain the volume of carbonic acid gas within a satisfactory degree of correctness in the following manner:—Obtain six white glass-stoppered bottles, dry and clean, capable of holding from 40 to 80 cubic inches of air; also a measuring glass that will show 3 cubic inches of liquid. Now take a bottle holding 40 inches of the air to be tested and put 3 cubic inches of clear freshly made lime-water into this and shake well with the contained air. If the water becomes cloudy it will show that the carbonic acid exceeds 12 parts in 10,000 of air. In 50 inches of air, cloudiness in the same quantity of lime water will indicate 10 (or more) parts of carbonic acid per 10,000 of air. In 60 inches, 8 parts. In 70 inches, 7 parts. In 80 inches, a little under 6 parts. Thus if the 3 cubic inches of lime water, when shaken in 70 cubic inches of air, became cloudy, but did not do so in 80 inches, it would indicate that the air contained between 6 and 7 parts of carbonic acid gas per 10,000 of air. This latter, as will be seen directly, is an allowed degree of impurity in most cases.

It should be stated, in relation to judging the degree of vitiation of air by its odour, that the humidity of the atmosphere is a controlling factor. The degree or volume of moisture in air does not vary to any great extent in our country, consequently it does not need much consideration if the warming of a place is done by fires or direct radiation; but if the Plenum System of combined warming and ventilation or any method of warming by heated air be adopted, as it largely is in public buildings and institutions, then the humidity, or rather a want of it, may make the smell test less reliable. The figures just given were obtained with air of about normal humidity, namely, a humidity of 73 per cent. with a temperature of 63 Fahr. With an increase of humidity an odour is more quickly obtained, while

the reverse applies with dry air. Any method of warming by which air is made to pass over heated surfaces makes it dry (compared to its temperature), and if moisture is not added, or is added but to an insufficient extent, then, as stated, the smell test must be less trustworthy.

The atmosphere can carry a varying quantity of moisture according to its temperature. Not only can it carry this, but if the quantity is not in proportion to the warmth the air will be dry. Thus air at, say, 35° Fahr. will contain about 2 grains of water per cubic foot, to be normally humid (it can carry $2\frac{1}{2}$ grains); but if this air is heated to 60° without obtaining added moisture it will be dry, as it then needs about $4\frac{3}{4}$ grains per foot to be normally moist. This added degree of moisture is usually picked up naturally in the ordinary way, but when air is heated by passing over enclosed batteries of heating surfaces, and from these delivered to a room in large volumes, an artificial means of adding water must be provided.

The quantities of water that air is capable of absorbing to become saturated are as follow:—

Deg. Fahr.	Grains per Ft.	Deg. Fahr.	Grains per Ft.
30	$2\frac{1}{8}$	50	$4\frac{1}{4}$
35	$2\frac{1}{2}$	55	5
40	3	60	$5\frac{7}{8}$
45	$3\frac{5}{8}$	65	$6\frac{7}{8}$

The air composing the outside atmosphere, however, is seldom saturated, the usual degree varying from 73 per cent. in summer to 89 in winter, the average for the year working out at 82 per cent. In moistening the air artificially therefore, as is necessary with an apparatus delivering warmed air, the added moisture should keep the air at, at least, 65 per cent. of the saturation figure for its temperature, as below this it will be dry.

The customary method of ascertaining the humidity of the air is by means of the dry-and-wet bulb hygrometer. This is a pair of thermometers, fixed side by side, one of which acts in the usual way, while the other has a piece of absorbent material (like wick) covering its bulb and extending down into a small jar of water. The water travelling up the wick on to the bulb might be thought to become of the same temperature as the air, but instead of this it is continually evaporating, the degree of evaporation agreeing with the dryness of the air. The evaporating process has a cooling effect on the bulb, with the result that this thermometer registers a lower temperature than the dry one, and the difference in temperature indicates the degree of dryness. A proper degree of humidity exists when the two thermometers show a difference of 6 to 8 degrees, while 10 degrees verges on dryness. On the other hand, there should not be less than a 4 degree difference, as then the air will verge on being too moist. If the two thermometers both indicated alike, it would show that the air was completely saturated, no evaporation occurring.

As stated, the need and extent of ventilation is based on the presence of carbonic acid gas and its comparative volume. The freshest air, however, always carries some of this impurity, probably 2 parts in 10,000 volumes, while it rises to about 4 parts in towns; this latter being, for towns, considered as pure air. In manufacturing centres this figure is exceeded, yet by good ventilation the standard of allowed impurity (about 8 parts to 10,000 in large centres) can be kept even in schools and rooms containing a full number of persons. Outside those districts having, naturally, a more or less poluted atmosphere the allowed degree of impurity is about 6 parts, or, more accurately, 2 parts per 10,000 in excess of the outer air.

There is no practical way of dealing with the carbonic acid gas so as to eliminate it from the air of rooms and so leave the contained air pure; nor would this be desirable, for many reasons. Instead of this, ventilation is resorted to, so as to displace the whole air contents of the rooms, and replace these with quite new air from outside; and ventilation may therefore be described as the substitution of fresh air for vitiated air. This, as will be seen, must be done to a sufficient extent to keep the proportion of carbonic acid gas (which is being constantly produced by the occupants of the rooms, gas-burners, etc.) down to the allowed limit of impurity; therefore the greater number of people there are in a room, or place, the greater must be the volume of air continually entering and passing through it. On this account the volume of air to be dealt with is always calculated at per person, also, where it appears desirable, per gas-burner.

An adult person gives off 0.5 to 0.6 cubic feet of carbonic acid per hour, and to maintain a standard of purity of 2 parts of CO_2 to 10,000 of air (in excess of the outside air) it is necessary that each adult, in health and in repose, have 2500 cubic feet of air per hour. If undergoing moderate exertion, an adult needs one-fourth more air, owing to his producing more CO_2, and this has to be remembered in factory and similar buildings. A gas-burner yields a greater volume of CO_2 than a man, and is calculated as being equal to three adults, at least, and should have fresh air accordingly. In schools the infants are commonly allowed 1500 feet of air per head, with 2000 feet for scholars of full age. In sickness the figures given should be increased 50 per cent.

Although scarcely within the province of the ventilating engineer, it may be stated that the effects of ventilation may be interfered with by the space allowed each person in a fully occupied place like a school. In board schools the minimum space is 100 cubic feet per head; in factories and workshops it should be 250 feet; in barracks 600 feet is allowed, while in hospitals 1500 to

2000 feet is usual. It follows also that floor area should bear some relation to space; for, as a writer has said, people could become suffocated at the bottom of a well though the space above be unlimited. There is no gain in calculating space as being higher than 12 feet; and, for schools, the least floor area should be 8 square feet per scholar, while in hospitals each patient should have 100 square feet as a minimum. For ordinary purposes the floor area should be one-twelfth of the cubic space allowed.

In providing the needed supply of fresh air to rooms, regard has to be made to the velocity with which it enters and flows through. Cool air is perceivable as a disagreeable draught when travelling at a low rate compared with warmed air. It is usually considered that a movement of 3 feet per second is ordinarily too fast, though, should the air be raised to 62° or 65° Fahr., this rate of movement will not be noticed, at least not disagreeably. There are no objections to the air moving rapidly in the delivery ducts or tubes leading to a room, provided the movement is slow in the room itself. This is effected by making the delivery openings, with their gratings (or "registers"), of greater area than the ducts, usually in square trumpet-mouthed form, ensuring a gentle delivery and causing the air to spread out as it enters. For ordinary living apartments the velocity can be kept low at all points, as the air of such rooms does not require to be changed oftener than about three times per hour; but in fully occupied places, like schools, concert halls, etc., the question of velocity has to be considered in deciding the sizes of ducts and their delivery openings.

In dealing with the practical side of ventilating works, the subject must be divided into two parts, namely, that which is called NATURAL VENTILATION and MECHANICAL VENTILATION. In the former the air movement is obtained by flues, which might be called chimneys, from the fact that they have a regular active upward movement of air within them, and as such they are considered as extractors. They do not have such a powerful draught within them as chimneys have, as their temperature is so much lower; but, broadly speaking, the air movement is sufficient to make this mode of obtaining the needed change of air occur satisfactorily. There are very strong exponents of natural ventilation, though in some cases reliance is put in the extractive action which takes place when wind blows over the upper end of a flue or duct. A very brief experiment with a piece of tube (glass, if convenient) open at both ends, but having a loose fitting ball of cotton-wool in it, will show that quite a light breeze over the upper end will cause the wool to rise. This movement is not due to any difference in temperature, but wholly to the exhaustion of air within the tube, by the horizontal movement of air over its top opening. It will be found that, by blowing slightly downward towards the top opening of the tube, there will still be a rise of air occur in it, but if the angle is too acute there will be a downward movement, like the familiar down-blow in chimneys.

The experiment will clearly show that the wind is an active, and sometimes very powerful, cause of an upward movement of air in a ventilating duct or flue, provided its upper end terminates high like a chimney, and does not, by terminating low, have down-blow occur in it. This latter detail has to be borne in mind, for while architects take every care to terminate smoke flues (chimneys) at sufficient height to prevent down-blow, they not infrequently give no consideration to this in the termination of air flues. It is necessary, as will be understood, if a natural up-draught is to be the means of effecting the desired air-change in the rooms below.

NATURAL VENTILATION

The "NATURAL" form of ventilation, while undoubtedly receiving aid by the passage of wind over its flues, does not rely on this action. Its chief reliance is on the difference in temperature of the air in the flues from that of the rooms and the outer air, this difference inducing a draught in just the same way as it happens in a chimney. A very useful table for ascertaining the volume of air that flues will deal with, and for deciding the sizes of flues, is as follows:—

Extraction of air in cubic feet per minute by a ventilating flue or shaft of 1 square foot area. These calculations make no allowance for friction, which will reduce the figures by one-third to one-half, according to the state of the interior surface of the flue. (From *Hood on Warming Buildings*, by Frederick Dye, M.R.I.)

Height of the Flue in Feet.	Difference in Temperature of Air entering the Flue and the outside Air.			
	15° F.	20° F.	25° F.	30° F.
15	245	284	318	348
20	285	330	368	404
25	318	368	410	450
30	347	403	450	493
35	376	436	486	531
40	403	465	518	570
45	427	493	551	605
50	450	518	579	635

Architects have, apparently, a difference of opinion as to whether the flues or shafts carrying the warm vitiated air from rooms should go up as separate flues (as chimneys always do) or whether they should join at convenient points and ultimately terminate at top in one or more outlets of large area. The latter is the usual — and somewhat necessary — plan when the ventilating arrangements are introduced after the building is up; and when, of necessity, the flues have

to be of sheet metal on the faces of the walls. If a natural draught is to be relied on there can be no doubt whatever that separate brick-built flues are best, but the other plan can be adopted when necessity makes it compulsory, or if it is proposed to use some auxiliary aid to assist the air movement. Every one having to do with chimneys knows the peculiar, and commonly bad, results frequently obtained if two or more join one another, and the same must apply to air flues; but if something is introduced at the upper termination of the air flues to assist or induce the

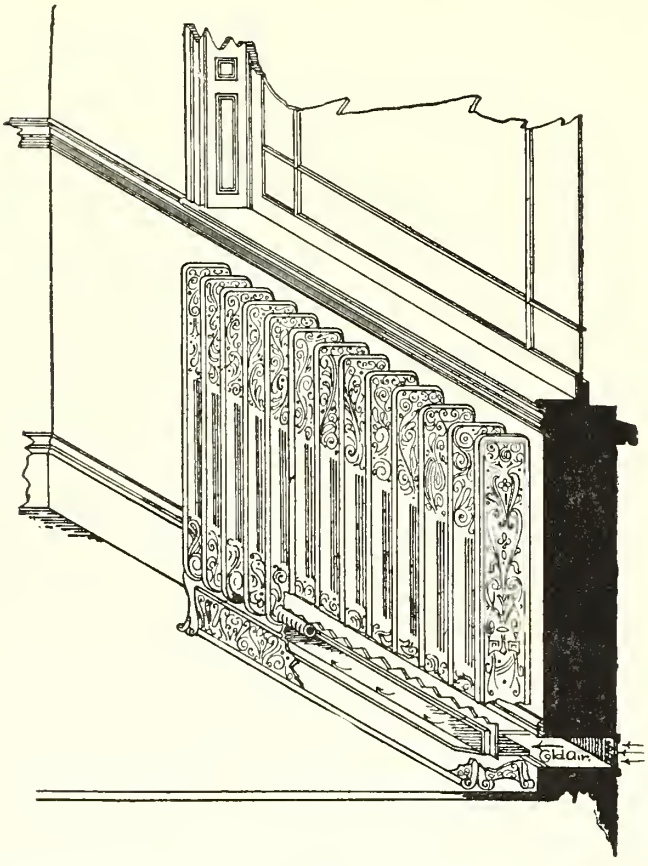


Fig. 69.

draught, then the joining of flues will give good results. The assistance referred to would be in the nature of a powerful gas ring or, more usually, a mechanically propelled air-extracting fan. Of course, the latter arrangement would come under the heading of mechanical ventilation.

Assuming that a system of natural ventilation (and the same applies to mechanical ventilation) is accompanied by a means of warming the air, the methods adopted for this may be introduced here. No building, as a bank, a store, school, institution or large place of business, all of which would be systematically ventilated, is ever without a heating installation, and, in the majority of cases, this is arranged so as to warm the air as it enters. It would not be reasonable to warm such places without doing at least something to raise the temperature of the large volumes of air that the ventilating arrangements bring in. In imparting warmth to the air, draughts are not only avoided, but ventilation (natural) is aided, as will be understood.

One form of air-heating appliance which commonly appears is the ventilating radiator. This is a radiator which is visible in the room, but is directly connected with the fresh-air inlets, as Fig. 69 shows. This needs no further description than to say that, in finding the area of radiator surface to afford a certain temperature, 25 per cent. must be added, if the radiator is of the ventilating kind. These radiators have valves fitted in their bases to control the flow of air, and it is argued that by this means the radiator can be made to heat and reheat the air of the room, when there are few people in it and the vitiation trifling, thus effecting a saving in fuel compared with the heat units taken by full ventilation.

In Fig. 70 is afforded a view of an "indirect" radiator, not visible in the room and devoted wholly to warming the air before it enters. This is connected up as a radiator or stack of pipe would be, and is then

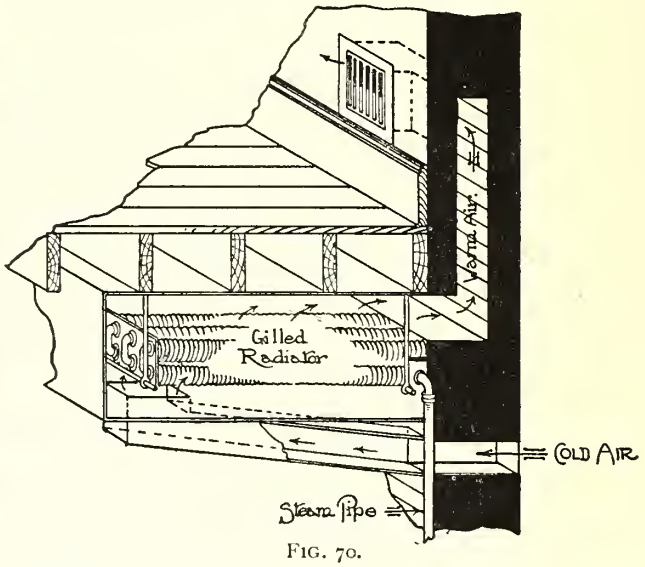


Fig. 70.

encased soundly, and provided with inlet and outlet ducts or flues as shown. A radiator, so fixed, can be made to heat more than one room, if its size is suitable. It is only necessary to take two or more delivery ducts from the casing; or to take one vertical duct of suitable size and branch it (with short branches) into rooms on floors above.

This illustration shows the warm air entering near the floor line. There is much difference of opinion regarding this point, and the subject will be found fully dealt with a little farther on. In no case should the delivery gratings or registers be in floors, as dirt gets swept into them. These radiators require to have 50 per cent. greater surface than the ordinary direct-heating non-ventilating kind, to afford a given temperature in the rooms.

The rule observed in calculating the sizes of ducts with indirect radiator work is to give them an area of 2 square inches for each square foot of radiator surface. Thus a 60 feet radiator would have ducts of 120 square inches, or say a tube or square form 17 by 7 inches. When delivery ducts go to upper floors, the proportion of 2 square inches per foot of surface is reduced. For a first floor 1½ square inch, and a second floor 1 inch, will do. If required, the cold-air duct need not be of quite so large an area as the delivery tubes; three-fourths to seven-eighths is sufficient.

In Fig. 71 is shown the plan of a warm-air heating installation in which a stove is used for affording the heat. The details are as follow:—

The heater has to be of a suitable make, having solid gills, or extended ribs and parts, to its exterior surface, the purpose of these extensions being to afford a largely increased heating area at a comparatively low temperature. In America these heaters are made in

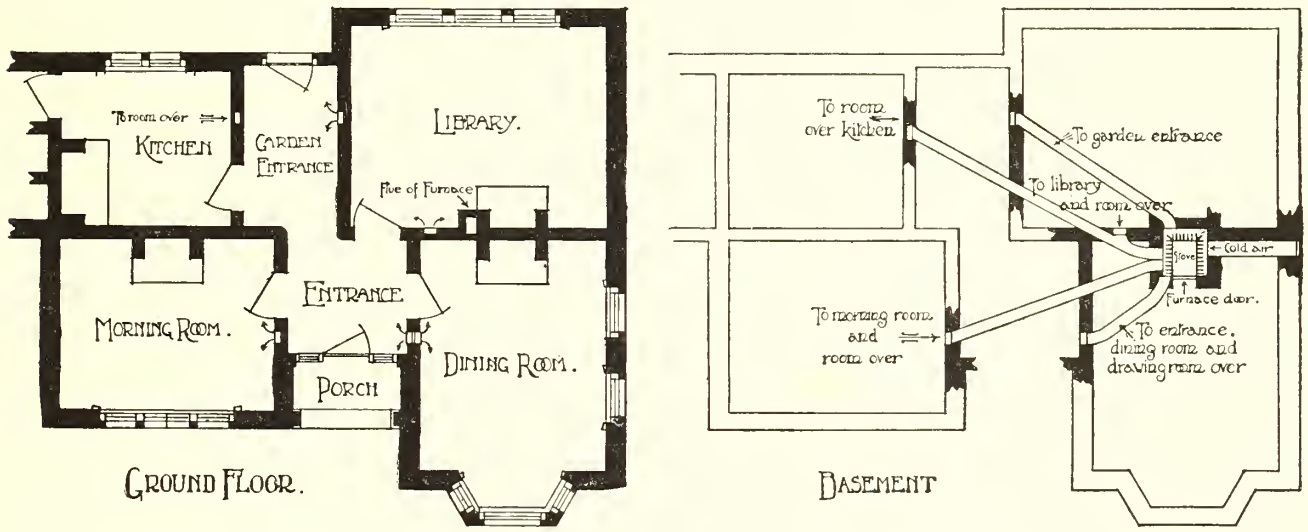


FIG. 71.

independent form with an iron air-casing around them, but in this country the stove is nearly always enclosed in a brick-built chamber. Fig. 72 affords a view of one of Musgrave's stoves with a longitudinal section of the chamber, showing some of the warm-air ducts leading from it. Although the chamber should be of confined area in order to prevent cold air getting through too freely, yet there must be an opening, and sufficient space within for cleaning the outer surface of the stove, as may be needed. All stoking is done, of course, from outside the air chamber.

The cold-air duct may be of earthenware drain pipe, if it can be obtained large enough for the job, failing which galvanised sheet iron may be used; or, in large jobs, a brickwork culvert is made, cemented smooth inside and with access for cleaning. This can come under the basement floor or by practically any convenient route, but it should have its opening on that side of the building which will cause it to be least affected by wind pressure. Particular care must be taken to draw the fresh air from a sweet source (not from a stable-yard, as was once seen). The outer opening must be grated, and lined with wire gauze, to keep out insects and débris, but as this retards the inflow of air this opening should be of double the area of the duct. It may be thought desirable to have two cold-air ducts, one on each of two opposite walls, and fitted with valves so that either may be used according to the direction of the wind, but this involves more attention than can generally be given. In certain cases the air may need filtering, in which case a frame covered with muslin or cheese-cloth may be used, but this requires the opening to be of so large an area (owing to the flow of air being so retarded by the cloth) that it is never resorted to unless absolutely necessary. The cloth, too, has to be frequently changed, probably once a week in manufacturing districts. A different plan is adopted with large Plenum works to both filter and moisten the air, as is referred to later.

Provision must be made to moisten the air (as already explained), and this is effected by placing a pan of water in the heating chamber. The pan can be in communication with a small cistern outside, fed either by hand or a ball valve, and a hygrometer, must be used to test and decide the amount of water that the pan should carry.

The warm-air delivery ducts may be of earthenware drain pipes, securely jointed to the ground floors, with either brick-built or sheet-metal vertical ducts to upper floors. All joints in basement pipes must be soundly made, or there will be a proportion of basement air delivered into the rooms. Horizontal ducts should be given a slight rise like hot-water pipes.

The grated openings of warm-air ducts, where they come in rooms, should be on the side walls and not in the floors. All delivery openings should be larger than

the ducts connected with them, so as to reduce the velocity (not volume) of discharge. Added to this, the opening must be made still larger to allow for the fact that the grating—a good open grating—has but two-thirds its area clear space, the remainder being metal. The delivery gratings should therefore be of a total area equal to double that of the warm-air duct, a duct of 50 square inches having a square-shaped trumpet mouth, to receive and be fitted with a 10 by 10, or 12 by 8-inch grating.

In ordinary living rooms there usually exist chimneys,

Stoves or heaters: about 8 feet of low-temperature surface per 1000 cubic feet of space to be served.

Cold-air delivery ducts, three-fourths to seven-eighths the area of all the warm-air ducts. The inlet gratings, lined with wire gauze, to be double this area.

Warm-air delivery ducts 50 square inches area per thousand cubic feet of ground-floor space to be served; 40 square inches for first floors, 32 square inches for second floors. Gratings or registers to these to be of double area, including the metal part of the grating.

Extract flues or shafts, from ground floors 32 square

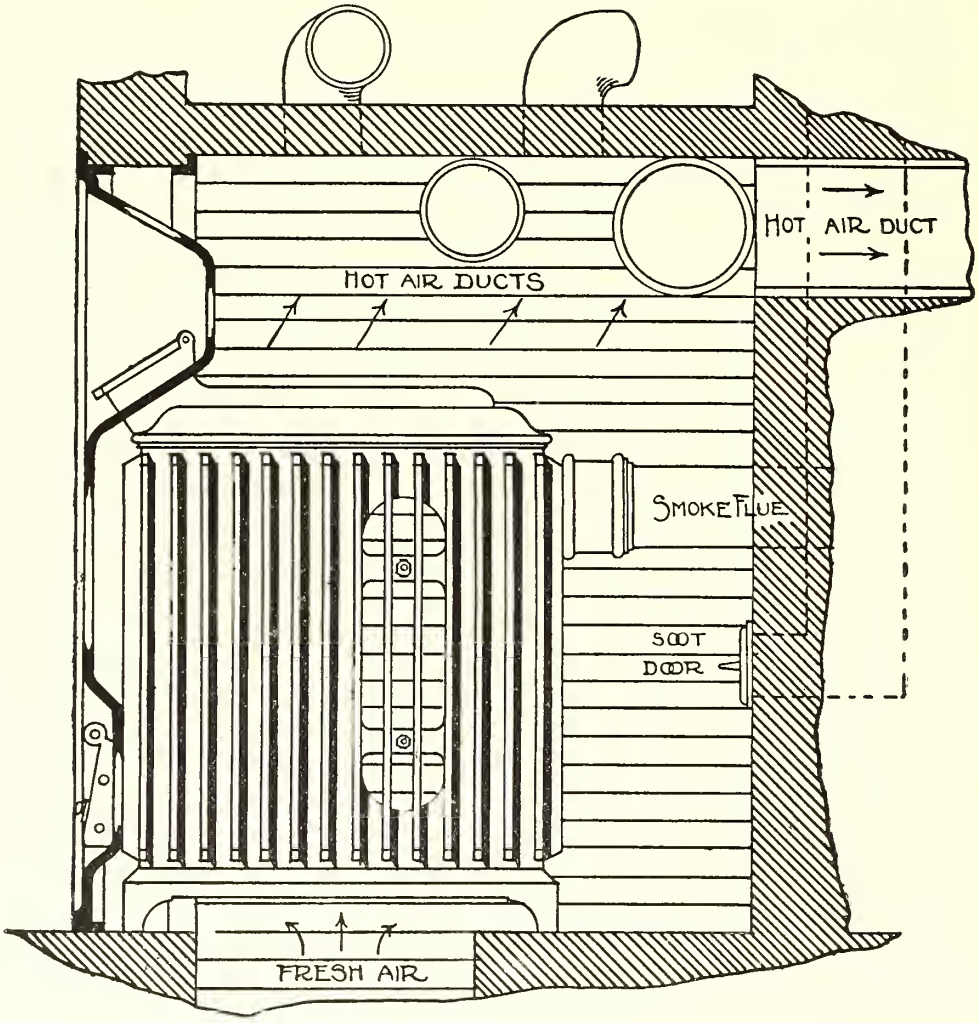


Fig. 72.

and these are relied on to act the necessary part of extract ventilating shafts, a part they usually perform sufficiently and well; but where chimneys do not exist or are not capable of dealing with the volume of air, extract flues or shafts are provided as already mentioned. These are best if brick built, as explained.

Proportions of Parts of a warm-air heating apparatus. These figures are for places occupied by a reasonable number of people. For schools, concert halls, and the like the calculations must be at per person, based on the figures previously given.

inches area for each thousand feet of space in the room; first floor, 40 square inches; second floor, 50 square inches; gratings or registers to these one-half larger, measuring over the metal part of the grating.

In regard to the positions of the inlet and outlet gratings or registers, considerable controversy exists, engineers having quite different opinions as to the best place to locate these. A long list could be made of the points, good or bad, that are possible, particularly as to whether both should be above or below the breathing line, or one above and one below, which should be

above or below, and what positions they should occupy in relation to one another. Of course, the idea aimed at is to get the air movement to occur in every part of the room as uniformly as possible, and to leave none moving too sluggishly or stagnant. The broad outcome of this, when dealing with warmed air, is that the greatest favour is given to putting both gratings on the same wall, one low and one high (not less than 7 feet above floor line), the wall to be an inner wall and facing an outer wall. There is no doubt about this being best, and from experiments made, and the experience gained by several engineers, there is little hesitation felt in saying that all parts of the room get their share of air movement by this arrangement. Fig. 73 illustrates this, showing the air movement noticed in experiments made.

An argument used in opposing the arrangement just shown is that the air movement brings down the vitiated air, products of respiration, etc., past the breathing line. The reply to this is that for these to come down they must first go up, and this they never do. On the other hand, the descending current does not flow past soiled or doubtful clothing of the occupants of the room, and, most importantly, it does not carry up any dust from the floor to the breathing line. The products from burning gas have to come downwards, but as a rule this is a minor item, and quite commonly has no existence.

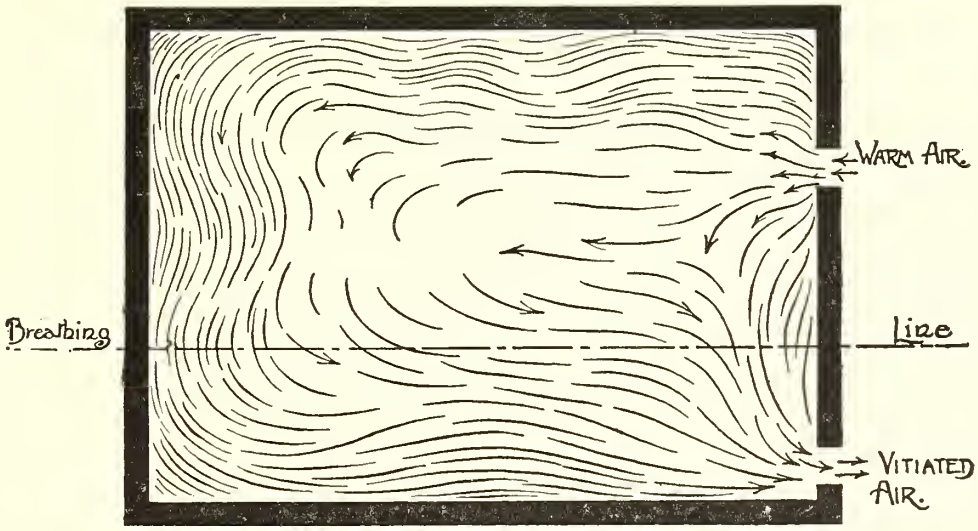


FIG. 73.

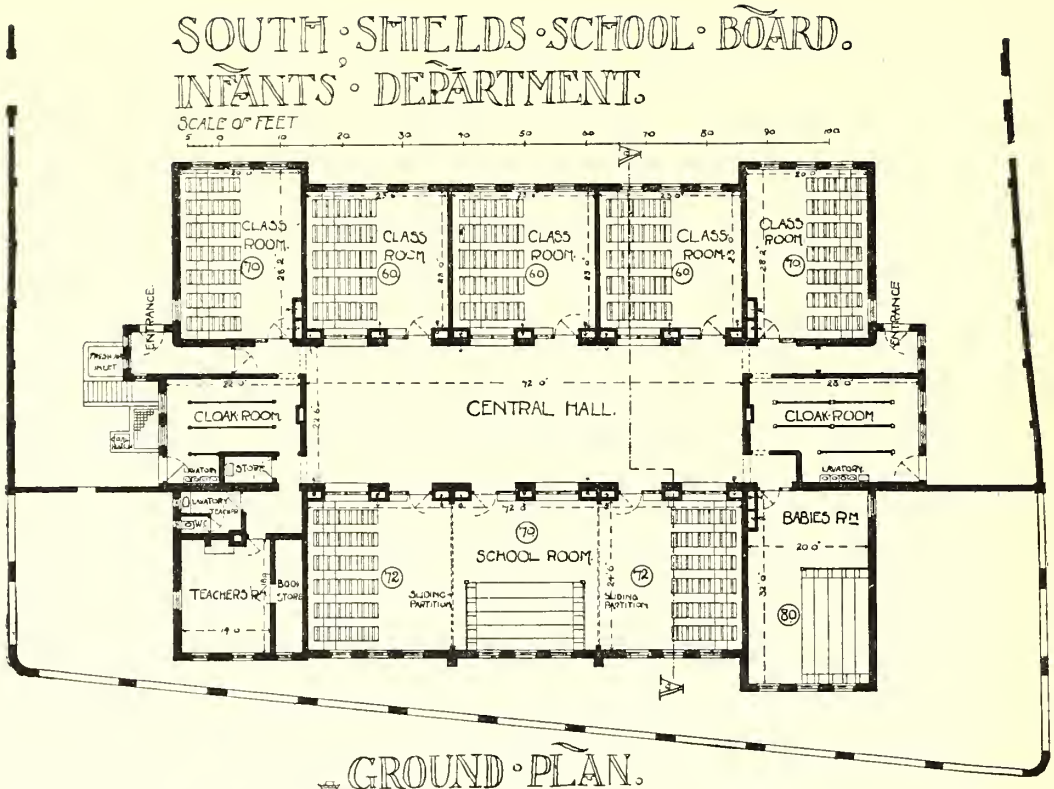
MECHANICAL VENTILATION

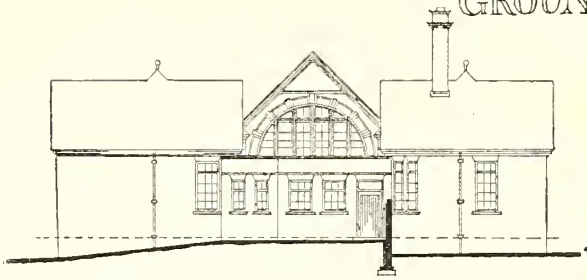
Mechanically induced air movement is carried out by fans or air propellers, and has the advantage of being "positive" in its action, which no other method of obtaining air movement truly is. It is independent of weather, wind, or temperature; the air can be warmed more precisely, and the whole is capable of very exact control. In many cases exhaust steam is used for the heating, so that this detail costs comparatively nothing, and the power required to propel the air is of small cost also.

There has been a divergence of opinion as to how the air should be dealt with, whether the vitiated air should be extracted, leaving the new air to flow in, as, of course, it freely will through the openings provided; or, whether the new air should be driven in under sufficient pressure (very slight) to force the air in the rooms—the vitiated air—out through the openings provided. The latter is the working principle of the PLENUM or pressure system, and one of its advantages is that, the air of the rooms being under a light pressure, every opening (other than the inlets provided), whether around doors or windows or elsewhere, has air passing outwards through it, and no draughts or undesirable air movements can occur. Ventilation, by a fan used exhaustively, requires the air propellor to be placed at the highest part of the building, as a rule, or at a distant point from the inlets, with the ducts conveying vitiated air leading to it. With this method, therefore, every opening in a room, whatever its size, or wherever it leads from, will probably act as an air inlet, in consequence of which many unexpected results transpire.

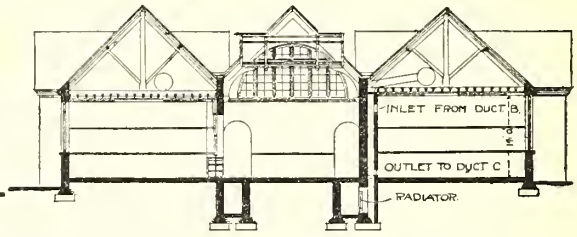
With the Plenum System the air propeller is fixed so as to come between the outer air and the fresh-air inlets of the room, and, communicating directly with both, the air is driven into the room. There can be no doubt about the superiority of the Plenum over the Exhaust method, and, except to meet some special requirement, it may be said that the latter has fallen into disuse, while the former is employed exclusively when mechanical ventilation is decided on. As previously stated, the action of the Plenum System is positive in causing the circulation of air, besides which it admits of heating the air by a single heater.

In Fig. 74 are given the particulars of a Plenum

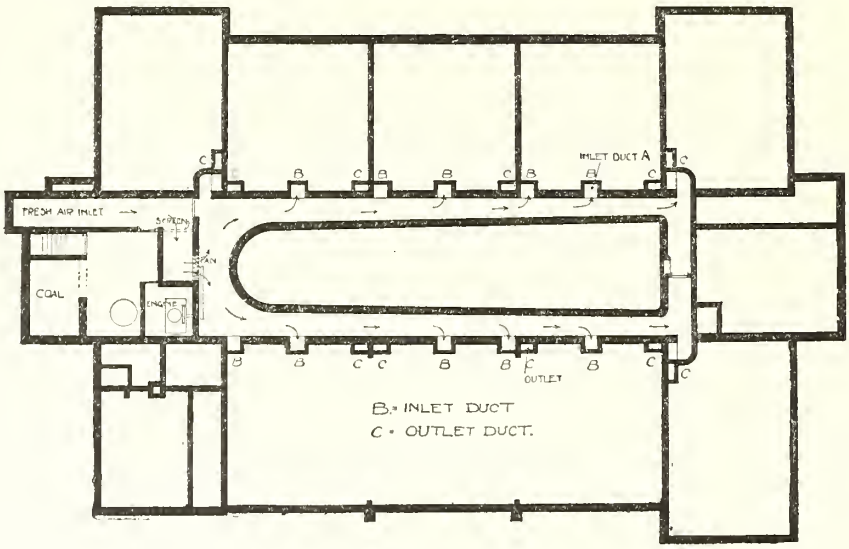




SIDE ELEVATION.



SECTION ON A·A.



BASEMENT · PLAN.

J.W. Donald
Architect.

FIG. 74.

installation in an Infants' School, previously illustrated and described, to afford warmth and ventilation in winter, and ventilation only in summer.

In the basement plan will be seen the fresh-air conduit, this having its inlet just above ground level (shown on the ground plan). . At a point between the inlet and the air propeller or fan is a screen for filtering the air. This, in suburban or rural districts, is a frame carrying wire gauze, its purpose being to arrest insects and floating débris. It is important that access be

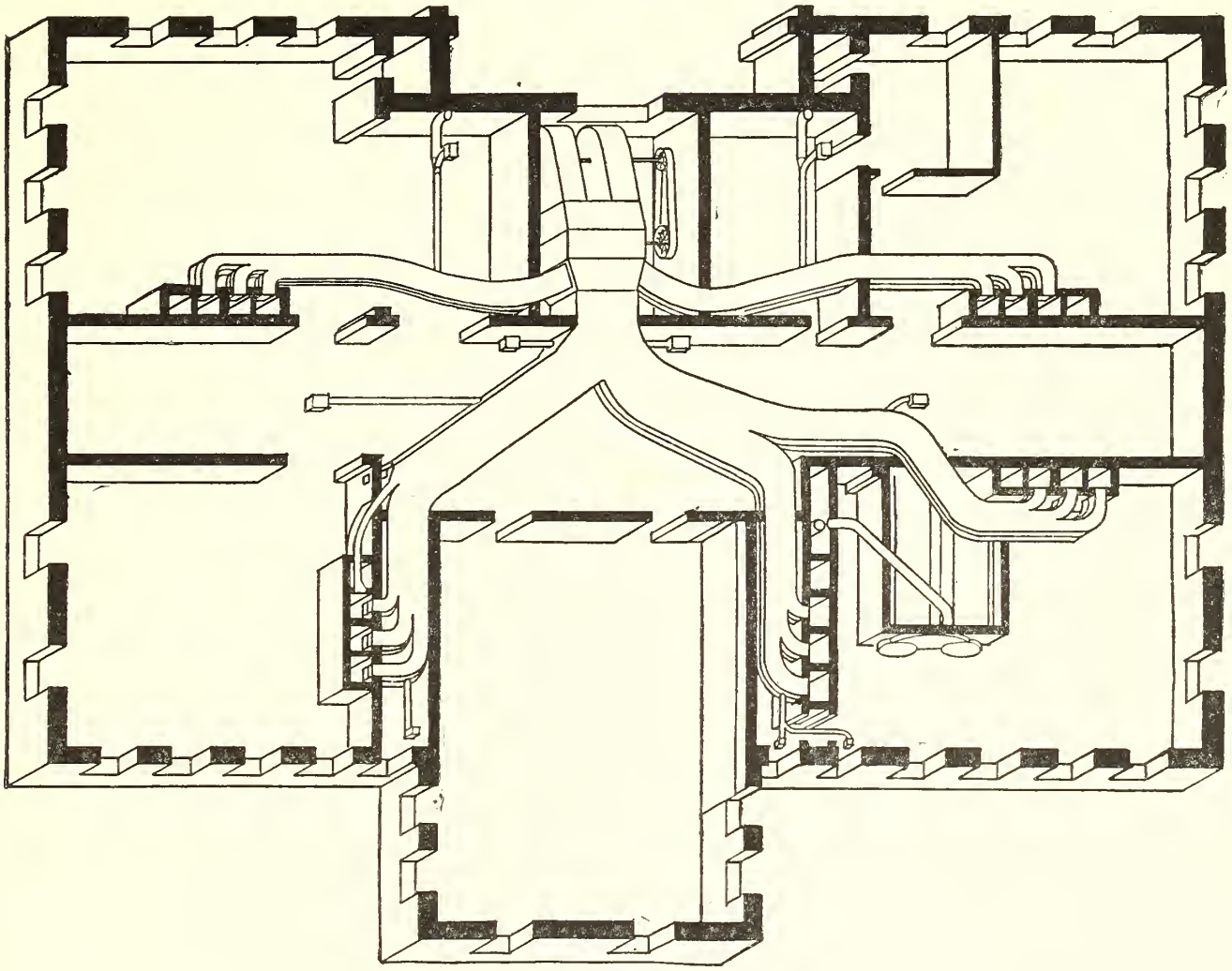


Fig. 75.

given to this, for, as stated, it arrests many things, a number of which remain on or in its mesh. The surface must be periodically brushed, or it will retard the passage of air to a very noticeable extent. When the air carries impurities in a fine sta e, as in manufacturing districts, recourse has commonly been had to coarse muslin, or cheese cloth, as the filtering material. This is an excellent filtering medium, but it requires very frequent cleaning or renewal. There is now most favour shown to a coke screen, this being about a 4-inch thickness of small coke held between two surfaces of small wire netting or coarse metallic gauze. Where convenient, arrangement is made for flushing this screen with water to cleanse it.

After passing the screen, the clean air is next carried through the fan and enters the main horizontal ducts—sometimes spoken of as culverts, when built of brickwork. Leading from these are the many vertical ducts, marked B, leading to the rooms. The delivery openings from the ducts B are situated on side walls, facing outer walls as recommended, and deliver the air about 11 feet above floor line. This high delivery, combined with low outlets for the vitiated air, will be found discussed later on. The outlets for vitiated air are also on side walls—the same walls as the inlets—situated at a low point just above skirting level. These shafts or flues proceed up and join a main shaft, which is shown in the roof space. The used air can be discharged directly into the open air, if desired ; but the roof space quite commonly receives it, and thence it escapes into the outer air as best it may ; though special openings must be provided if the roof be well

constructed, say with boarding or felt under the slates, and the beam-filling properly done.

The heating of the air is not accomplished by a single heater in this case. Instead of this, each vertical duct has its own heater, in the form of a radiator, at its base. This will be seen in the section on A A. It is an arrangement that admits of independent regulation of the warmth of the rooms without varying the volume of air.

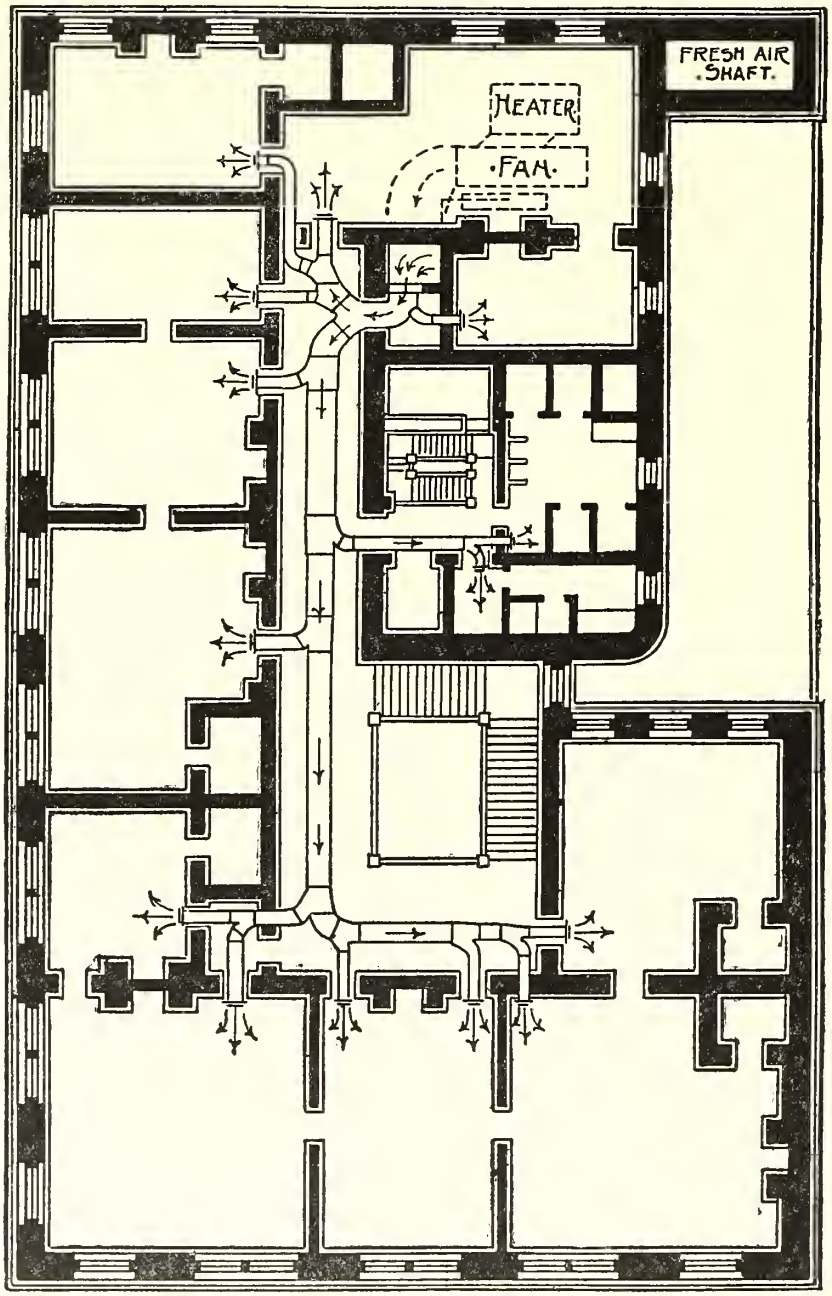


Fig. 76.

Fig. 75[1] shows, in isometric projective, another method of treating a school building (or any similar structure) that extends to three floors. In this case, instead of brick culverts for the main ducts, these are of sheet metal and of rectangular form, and this illustration presents a good idea of the easy curves that should be made when branching or dividing ducts of any kind.

The fan in this case is of the blow-through kind, the air being driven through—not drawn through—the heating stack. The heater is enclosed in the space shown on the delivery side of the fan. In this installation was provided a novel detail, not shown in the

[1] This and the two succeeding illustrations represent works carried out with the Sturtevant Company's fans and heaters.

illustration, this being a "tempering coil." It consisted of a coil to temper the air which came to the fan and heater proper; and as this coil was heated by the exhaust steam from the engine employed to drive the fan, the heat units afforded were obtained free. Another detail not appearing is a space beneath the heater stack, so arranged that, by operating a damper, the passage of air can be regulated so as to go through the heater or beneath it, or part each way, so that its temperature may be varied according to the weather.

A further example may be given in Fig. 76. This is the plan of one floor of an office building having several floors, each being treated as shown in this illustration. The fan is of the "exhauster" type (which has nothing to do with the exhaust system of ventilation) the air level with the bottoms of the ducts, and with high corridors this is in no way objectionable.

A final example may be shown by Fig. 77. This, again, is a quite different undertaking, the building being a manufactory. The fan is of the type which draws the air through the heater and delivers it to horizontal ducts as shown. These are branched into vertical pipes, each having outlets at four floors. The central pipe duct has four outlets at each floor, the idea being to discharge in a line with the walls each way, also at an angle of 45° in two directions. It was thought best to adopt this plan, owing to the building being of such open construction and having a large glass area. Ordinarily the pipe ducts would have been up one side wall, with outlets to discharge towards the other.

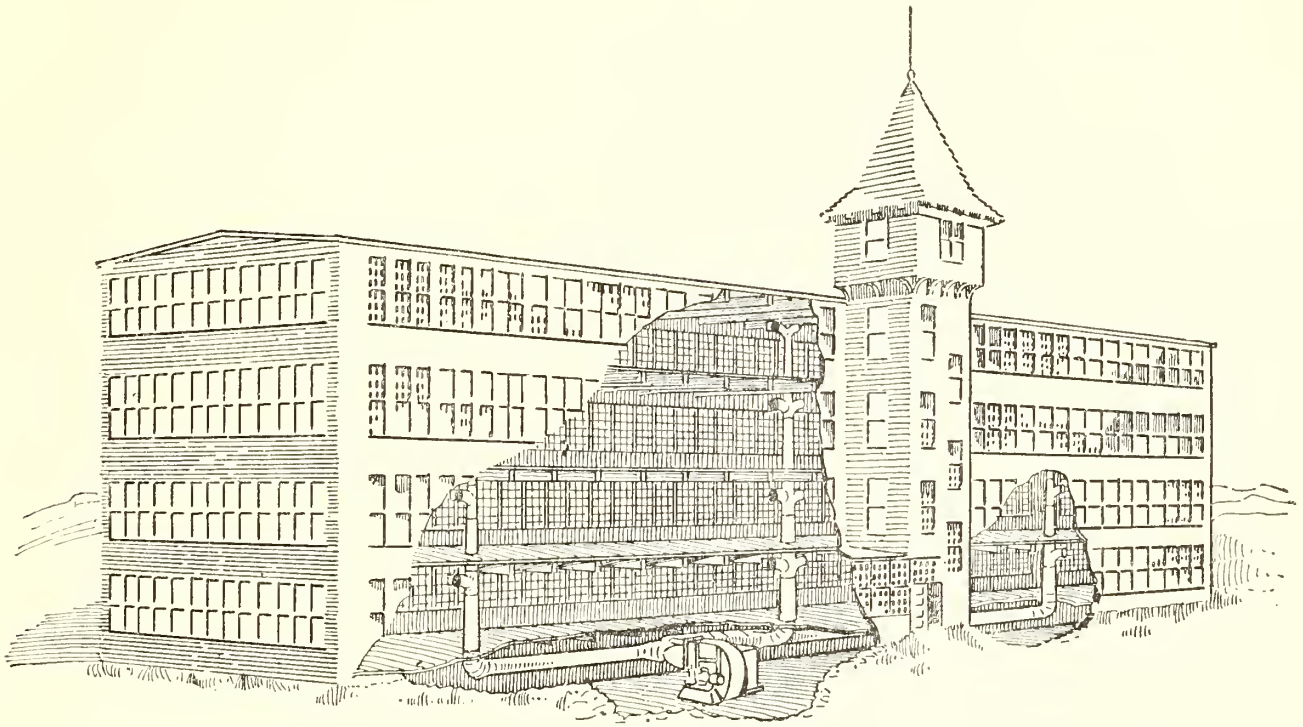


FIG. 77.

flowing through the heater to the fan and not being blown from the fan through the heater. From the fan (closely connected to it by a large duct) is a large vertical shaft built up in the building, and extending up to all the floors to be heated. In this shaft, at the ceiling level of each floor, is an opening from which a horizontal delivery duct is taken, beginning in full size, as the illustration shows, and then reducing as it is branched to the different rooms. The delivery at nearly all points is over door heads, but it could be made, of course, at any suitably good point. The main and branch ducts are of rectangular cross section, as flat as possible, and in the majority of instances these are not considered unsightly on the ceilings of the corridors. In cases, however, where the appearance is of first consideration a false ceiling is made extending across

In working out the details of a Plenum ventilating and heating system very few engineers make, or even work out, the specification for, their own fans; and few, even if they make the needed calculations for surface, construct their own heaters. These are all commonly obtained from a manufacturing firm who are specialists in these appliances, but the following particulars may be given. Many of the calculations which follow are based on those given by the Sturtevant Engineering Company, who make fans and heaters for every purpose.

The designing and manufacture of fans or air propellers is outside the province of this book, but it may be said that in choosing a fan a full size should be selected for low-velocity work, such as in schools, offices, institutions, etc.; while a smaller fan, worked

at a higher speed, is admissible in factory work where higher velocities are allowed, and are frequently necessary in order to force the air long distances. It must not be forgotten, however, that high speeds mean an increase in driving power, and loss by excessive friction in the ducts. There are so many considerations in the choice of a fan that it is best to let the size and speed be decided by the maker, who is, or should be, the best qualified to settle this important detail. Makers are prepared to do this, and guarantee results.

In arranging the delivery ducts from a fan the conditions must enter very largely into the scheme; for this, after a building is erected, is a different matter to running hot-water pipes. Correctly speaking, a building should have the details of all ducts and flues in its plans prior to erection, in which case the whole might be of brickwork, which is best, at the least possible cost. Failing brickwork, the earthenware pipe can be pressed into use in many places, but it is galvanised sheet iron that has to be relied upon chiefly when brick ducts are impossible. The chief point to remember with this material is that the joints must be made as soundly as possible, and all curves must be of the fullest possible radius.

The area of a duct is, of course, based on the volume of air required to pass through it, and while there is a leaning towards small ducts with high velocities, with unsatisfactory results, the extreme opposite of this would require ducts of such a size as to be prohibitive in cost. The general rule is to allow fairly high velocities in the main ducts where they leave the fans, and to reduce as the air proceeds to the rooms. A velocity of 2000 feet per minute is considered correct where the air leaves the fan. From this the velocity should drop to 800 and even to 500 feet in branch ducts, while that in the delivery duct should never exceed 300 feet per minute for dwelling or schoolrooms. In factory work the delivery may rise to a speed of 2000 feet per minute, while the velocity at the fan, worked at high speed, may then be as high as 3500 feet. As will be understood, velocity, after the air leaves the fan, is reduced by increasing the areas of the ducts and the delivery openings. It will be understood that to maintain an excess velocity or pressure at the beginning or base of each branch duct tends to keep all equally well served, and none are neglected or have variable results occurring in them.

The two following tables, published by the Sturtevant Company, afford all particulars for calculating the areas of ducts:—

NUMBER OF SQUARE INCHES OF FLUE AREA REQUIRED PER 1000 CUBIC FEET OF CONTENTS FOR GIVEN VELOCITY AND AIR CHANGE.

No. of Minutes to change Air.	Velocity of Air in Flue in Feet per Minute.												
	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
4	120	90	72	60	51.6	45	40	36	32.2	30	27.6	25.6	21.4
5	96	72.2	57.6	48	41.1	36.1	32	28.8	26.2	24	22.2	20.5	19.2
6	80	60	48	40	34.3	30	26.6	24	21.8	20	18.5	17.1	16
7	68.6	51.4	41.1	34.3	29.4	25.7	22.9	20.6	18.7	17.2	15.7	14.7	13.7
8	60	45	36	30	25.8	22.5	20	18	16.1	15	13.8	12.8	12
9	53.3	40	32	26.6	22.9	20	17.8	16	14.5	13.3	12.3	11.4	10.7
10	48	36	28.8	24	20.6	18	16	14.4	13.1	12	11.1	10.3	9.6
11	43.6	32.2	26.2	21.8	18.7	16.1	14.5	13.1	11.9	10.9	10.1	9.5	8.7
12	40	30	24	20	17.2	15	13.3	12	10.9	10	9.2	8.6	8
13	36.9	27.7	22.2	18.5	15.7	13.8	12.3	11.1	10.1	9.2	8.5	7.9	7.4
14	34.3	25.7	20.6	17.2	14.7	12.8	11.4	10.3	9.5	8.6	7.9	7.4	6.9
15	32	24	19.2	16	13.7	12	10.7	9.6	8.7	8	7.4	6.9	6.4
16	30	22.5	18	15	12.9	11.2	10	9	8.2	7.5	6.9	6.4	6
17	28.2	21.2	16.9	14.1	12.1	10.6	9.4	8.5	7.7	7	6.5	6.1	5.6
18	26.6	20	16	13.3	11.5	10	8.9	8	7.3	6.6	6.2	5.7	5.3
19	25.3	18.9	15.2	12.6	10.8	9.5	8.4	7.6	6.9	6.3	5.8	5.4	5.1
20	24	18	14.4	12	10.3	9	8	7.2	6.5	6	5.5	5.1	4.8

FLUE AREA REQUIRED FOR GIVEN VOLUME AND VELOCITY.

Volume in Cubic Feet per Minute.	Velocity in Feet per Minute.																										
	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2600	2700	2800	2900	3000	3100
100	48	36	29	24	21	18	16	14	13	12	11	10	9.6	9	8.5	8	7.6	7.2	6.9	6.6	6.3	6	5.5	5.3	5.1	5	4.8	4.6
125	60	45	36	30	26	23	20	18	16	15	14	13	12	11.3	10.6	10	9.5	9	8.6	8.2	7.8	7.5	6.9	6.7	6.4	6.2	6	5.8
150	72	54	43	36	31	27	24	22	20	18	16	15	14.4	13.5	12.7	12	11.4	10.8	10.3	9.8	9.4	9	8	8	7.7	7.5	7.2	7
175	84	63	50	42	36	32	28	25	23	21	19	18	16.8	15.8	14.8	14	13.3	12.6	12	11.5	11	10.5	9.7	9.3	9	8.7	8.4	8.1
200	96	72	58	48	41	36	32	29	26	24	22	21	19.2	18	16.9	16	15.2	14.4	13.7	13.1	12.5	12	11.1	10.7	10.3	9.9	9.6	9.3
225	108	81	65	54	46	41	36	32	29	27	25	23	21.6	20.3	19.1	18	17.1	16.2	15.6	14.7	14.1	13.5	12.5	12	11.6	11.2	10.8	10.4
250	120	90	72	60	51	45	40	36	33	30	28	26	24	22.5	21.2	20	19	18	17.1	16.4	15.7	15	13.9	13.3	12.9	12.4	12	11.6
275	132	99	79	66	57	50	44	40	36	33	30	28	26.4	24.8	23.3	22	21.8	19.8	18.9	18	17.2	16.5	15.2	14.7	14.1	13.7	13.2	12.8
300	144	108	86	72	62	54	48	43	39	36	33	31	28.8	27	25.4	24	22.7	21.6	20.6	19.6	18.8	18	16.6	16	15.4	14.9	14.4	13.9
325	156	117	94	78	67	59	52	47	43	39	36	33	31.2	29.3	27.5	26	24.6	23.4	22.3	21.3	20.6	19.5	18	17.3	16.7	16.1	15.6	15.1
350	168	126	101	84	72	63	56	50	46	42	39	36	33.6	31.5	29.6	28	26.5	25.2	24	22.9	21.9	21	19.4	18.7	18	17.4	16.8	16.3
375	180	135	108	90	77	68	60	54	49	45	42	39	36	33.8	31.8	30	28.4	27	25.7	24.5	23.5	22.5	20.8	20	19.3	18.6	18	17.4
400	192	144	115	96	82	72	64	58	52	48	44	41	38.4	36	33.9	32	30.3	28.8	27.4	26.2	25	24	22.2	21.3	20.6	19.8	19.2	18.6
425	204	153	122	102	87	77	68	61	56	51	47	44	40.8	38.3	36	34	32.2	30.6	29.1	27.8	26.6	25.5	23.5	22.7	21.9	21.1	20.4	19.7
450	216	162	130	108	93	81	72	65	59	54	50	46	43.2	40.5	38.1	36	34.1	32.4	30.9	29.5	28.2	27	24.9	24	23.1	22.3	21.6	20.9
475	228	171	137	114	98	86	76	68	62	57	53	49	45.6	42.8	40.2	38	36	34.2	32.6	31.1	29.7	28.5	26.3	25.3	24.4	23.6	22.8	22.1
500	240	180	144	120	103	90	80	72	65	60	55	51	48	45	42.4	40	37.9	36	34.3	32.7	31.3	30	27.7	26.7	25.7	24.8	24	23.2
525	252	189	151	126	108	95	84	76	69	63	58	54	50.4	47.3	44.5	42	39.8	37.8	36	34.4	32.9	31.5	29.1	28	26.9	25	25.2	24.4
550	264	198	158	132	113	99	88	79	72	66	61	57	52.8	49.5	46.6	44	41.7	38.6	37.7	36	24.4	33	30.5	29.3	28.3	27.3	26.4	25.5
575	276	207	166	138	118	104	92	83	75	69	64	59	55.2	51.8	48.7	46	43.6	41.4	39.4	37.6	36	34.5	31.9	30.7	29.6	28.5	27.6	26.7
600	288	216	173	144	123	108	96	86	79	72	66	62	57.6	54	50.8	48	45.5	43.2	41.1	39.3	37.6	36	33.2	32	30.8	29.8	28.8	27.8
625	300	225	180	150	129	113	100	90	82	75	69	64	60	56.3	52.9	50	47.4	45	42.9	40.9	39.1	37.5	34.6	33.3	32.1	31	30	29
650	312	234	187	156	134	117	104	94	85	78	72	67	62.4	58.5	55.1	52	49.3	46.8	44.6	42.5	40.7	39	36	34.7	33.4	32.2	31.2	30.2
675	324	243	194	162	139	122	108	97	88	81	75	69	64.8	60.8	57.2	54	51.2	48.6	46.3	44.1	42.3	40.5	37.5	36	34.7	33.5	32.4	31.3
700	336	252	202	168	144	126	112	101	92	84	78	72	67.2	63	59.3	56	53.1	50.4	48	45.8	43.8	42	38.8	37.3	36	34.7	33.6	32.5
725	348	261	209	174	149	131	116	104	95	87	80	75	69.6	65.3	61.4	58	55	52.2	49.7	47.4	45.4	43.5	40.2	38.7	37.3	36	34.8	33.6
750	360	270	216	180	154	135	120	108	98	90	83	77	72	67.5	63.5	60	56.9	54	51.4	49.1	47	45	41.5	40	38.6	37.2	36	34.8
775	372	279	223	186	159	140	124	112	101	93	86	80	74.4	69.8	65.6	62	58.8	56.3	53.1	50.7	48.5	46.5	42.9	41.3	39.9	38.5	37.2	36
800	384	288	230	192	165	144	128	115	105	96	89	82	76.8	72	67.8	64	60.6	57.6	54.9	52.4	50.1	48	44.3	42.7	41.2	39.7	38.4	37.1
825	396	297	238	198	170	149	132	119	108	99	91	85	79.2	74.3	69.9	66	62.5	59.4	56.6	54	51.7	49	45.7	44	42.4	40.9	39.6	38.3
850	408	306	245	204	175	153	136	122	111	102	94	87	81.6	76.5	72	68	64.4	61.2	58.4	55.6	53.2	51	47.1	45.3	43.7	42.2	40.8	39.4
875	420	315	252	210	180	158	140	126	115	105	97	90	84	78.8	74	70	67.3	63	60	57.3	54.8	52.5	48.5	46.7	45	43.4	42	40.6
900	432	324	259	216	185	162	144	130	118	108	100	93	86.4	81	76.2	72	68.2	64.8	61.7	58.9	56.3	54	49.9	48	46.3	44.6	43.2	41.8
925	444	333	266	222	190	167	148	133	121	111	103	95	88.8	83.3	78.4	74	70.1	66.6	63.4	60.5	57.9	55.5	51.3	49.3	47.6	46	44.4	42.9
950	456	342	274	228	195	171	152	137	124	114	105	98	91.2	85.5	80.5	76	72	68.4	65.1	62.2	59.5	57	52.6	50.7	48.8	47.1	45.6	44.1
975	468	351	281	234	201	176	156	140	128	117	108	100	93.6	87.8	82.6	78	73.9	70.2	66.8	63.8	61.0	58.5	54	52	50.2	48.4	46.8	45.3
1000	480	360	288	240	206	180	160	144	131	120	111	103	96	90	84.7	80	75.8	72	68.7	66	62.6	60	55.4	53.3	51.4	49.6	48	46.4

In arriving at the surface required in the heater, it has first to be stated that steam is the heating medium,

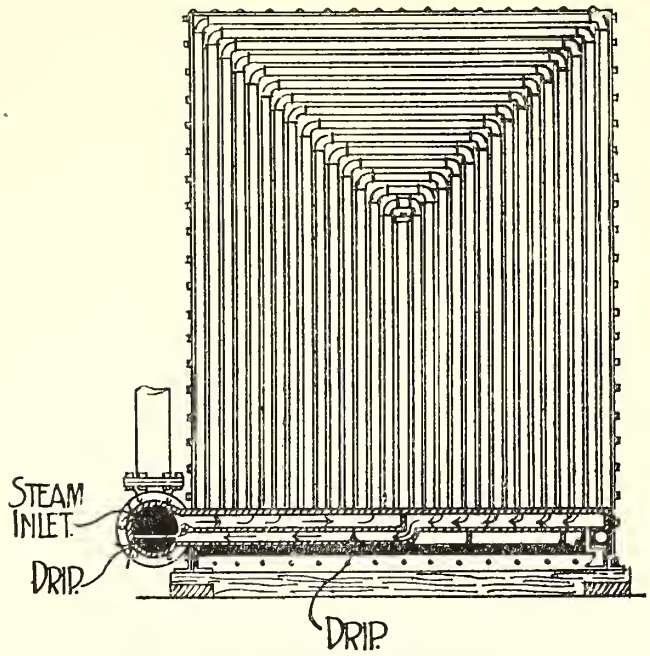


Fig. 78.

and this may be exhaust steam at about 216°, or may be live steam at any pressure and temperature up to, say, 80 lbs. per square inch. The heater is now invariably built up of wrought tube secured to suitable base sections, as shown in Fig. 78, each section carrying two or four rows of pipe. The ill effects of expansion and contraction are avoided by this means, while movement lengthwise is allowed for by the ball bearing. These heaters commonly have one section without communication with the remainder, this section being heated by the exhaust steam from the fan engine. This is supposing, of course, that an engine is devoted to the fan, which may not be the case in mills and factories. By utilising the exhaust steam from the fan engine there is, needless to say, a distinct fall in the ultimate cost of running the fan. When desired, these heaters can be further divided up so as to use exhaust steam from other engines in one part and live steam in the other.

The area of surface required in the heater, for given results, may be computed from any of the recognised tables, but the common custom is to allow one lineal foot of this pipe (1 inch) to a given number of cubic feet in the building. In factories and mills it is calculated that a foot of pipe can serve 100 cubic feet of space if the pipe is heated with exhaust or low-pressure steam, or 150 cubic feet for high-pressure steam. This is supposing that all the heated air goes to waste after once passing through the building, and that the air is changed three times per hour. In assembly rooms, schools, and buildings having the occupants closely congregated the changes of air

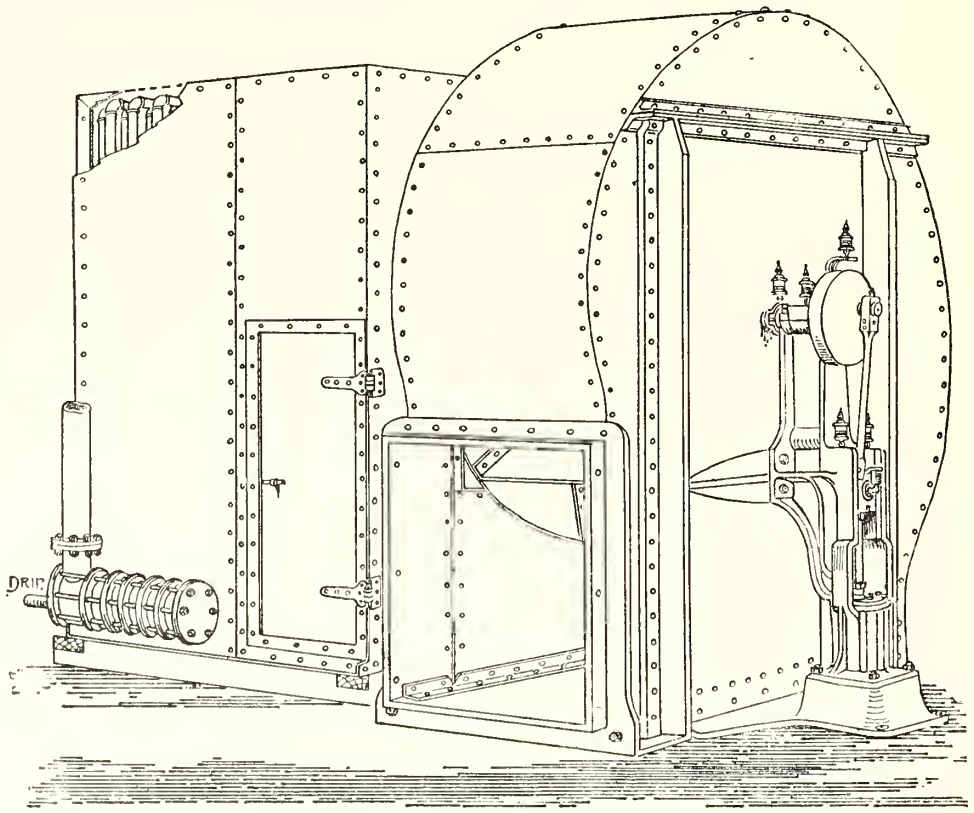


Fig. 79.

have to be more frequent, with the temperature a little higher, and the allowance is then either 70 or

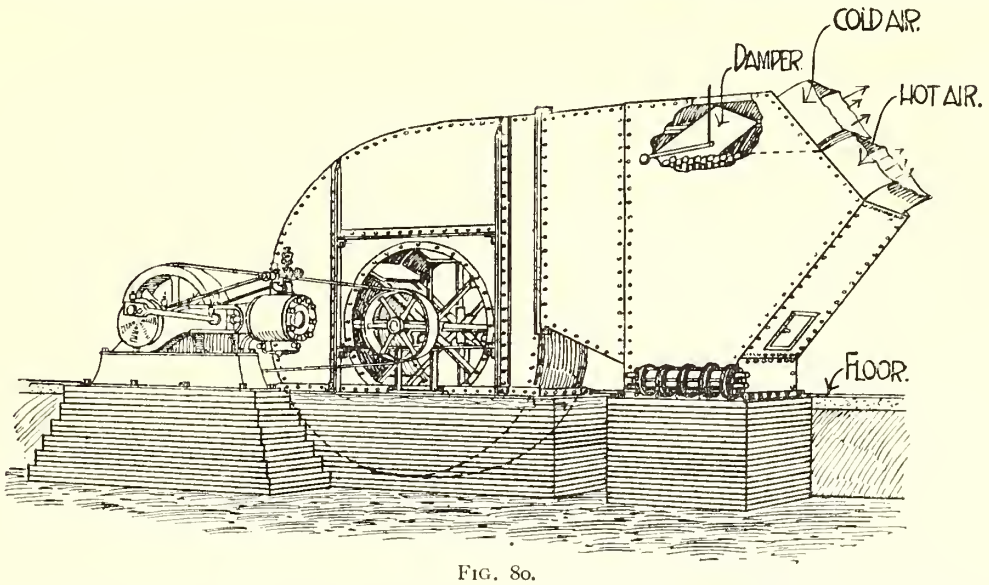


FIG. 80.

100 cubic feet to each foot of pipe, according to whether low or high-pressure steam is used.

In Fig. 79 is shown a fan and heater complete, a corner broken away from the heater case disclosing the arrangement of the pipes within. The engine operating the fan has its cylinder below the fan axle. It will be seen that the outfit is of the design that draws the air through the heater. The fan can be made to deliver at floor level or into underground ducts, or at a high level horizontally; or again, a vertical delivery can be arranged if it best suits the conditions.

In Fig. 80 is illustrated a combined fan and heater, of the blow-through type, specially designed for what is known as the "double-duct" system. This system of work is finding favour for schoolwork, or similar buildings, in which the air supply has to be constant regardless of the outdoor temperature. This result can be obtained without double ducts, by simply allowing cold air to mix with the heated air, as already mentioned, but this latter plan does not admit of independent regulation of temperature to each and all of the rooms. In many cases independent regulation is not needed, but when it is recourse is usually had to twin ducts.

With the introduction of hot and cold-air ducts there came the necessity of devising a regulating device, easily operated, by which the quantity of cold or warm air, making up the whole volume delivered, could be regulated. This device has been named the "mixing-damper," and Fig. 81 will give a general idea of its operation. The ends of the twin ducts, where they terminate in the single-delivery duct, are fitted with a section of tube—a cylinder to act as a damper. The tube does not serve any purpose as a tube, but is a form of damper that operates with more certainty, and is more easily fitted, than a flat plate. Scarcely any description is needed, as it will be seen how readily the passage of air from either duct can be regulated

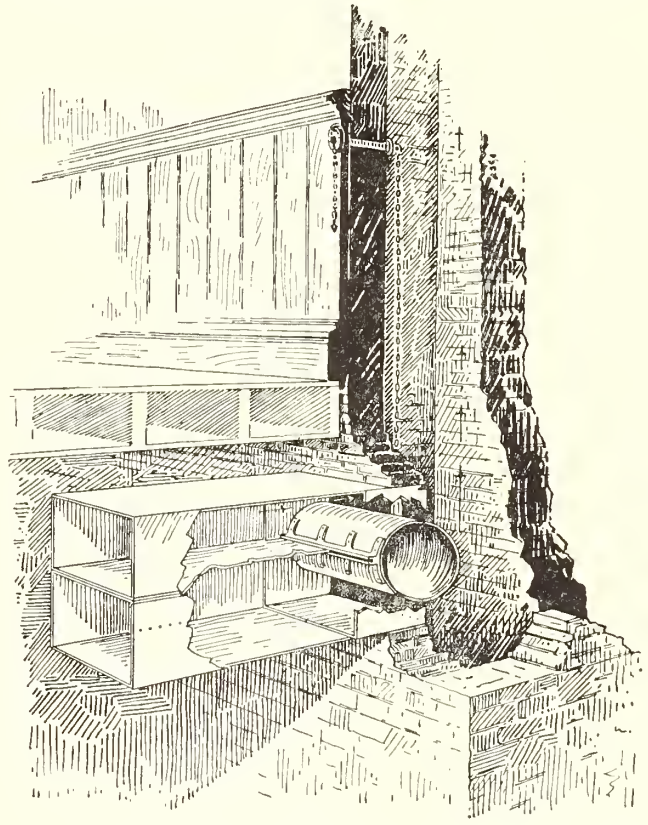


FIG. 81.

by the weighted cord which appears in the room above.

CHAPTER IX

GRATES AND STOVES (FOR COAL FUEL)

Grates

There are two special advantages possessed by the open visible fire which, though more sentimental than real, have done much to keep the open grate in favour, and are likely to do so for a long period to come. To an engineer's, or any technical mind, the small percentage of heat units obtained from a given weight of coal, and the gross production of soot, must always condemn the open fire, but the average user invariably signifies a strong liking for the cheering effect that the open fire produces; and the majority argue that radiant heat is preferable to all else. It is quite true that the sight of a cheerful fire is agreeable in cold weather, but if the fire-lover were asked if the visible fire was desirable and pleasing on a summer's day the answer would be in the negative. It is just so in a house properly warmed by hot water or other means; no desire for a visible fire exists, nor is the thought of it particularly agreeable. It is quite possible, with several means of heating, to have summer to all intents and purposes in the house, day and night, all through the winter, and the open fire is only remembered as a source of dirt, draughts, and extra servants' duties.

In regard to the heat given off by the open fire, this is wholly radiant heat, and its claim for good qualities is based on its being the same as the sun's heat, which also affords radiant heat wholly. Radiant heat, however, is not quite so agreeable as is supposed. Were we to rely wholly on it we should, most of us, perish of cold. This is painfully evident to those who climb high mountains or ascend in balloons. The most agreeable and healthful time a man knows is that of a summer evening, when radiant heat is absent. The pleasant warmth is then due to air that is warmed by the earth and objects which have been heated by the sun. An open fire affords little heat of a generally pleasant character until it has warmed the walls and furnishings of the rooms, and these in turn have warmed the air, and one of the most valuable and universally adopted improvements in open grates has its success based on the fact that it throws heat downwards from the fire on to the floor of the room. No one, male or female, having once experienced hot water, warm air, or steam heat in their homes will ever remember the open fire except as a usually handsome but always a dirt-producing contrivance.

The open grate is a development of the open hearth, which is depicted by Fig. 82, and which was the first form of fireplace, if it can be called such, with which a chimney was used. They are still to be seen and, for burning fallen or split wood and the combustible débris of the country, they serve very well. The heat given off is comparatively small, while the draught induced by these huge chimney openings is such as to make the old-fashioned high-backed settles and chairs a real necessity.

The fireplace which succeeded the open hearth, by

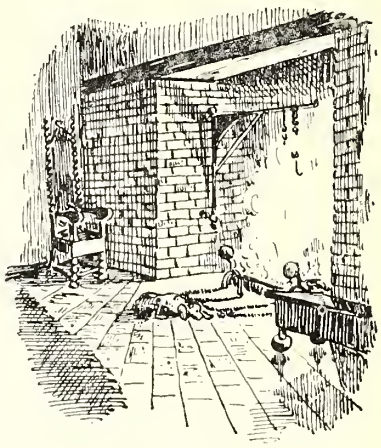


Fig. 82.

natural sequence as will be seen, was the fire-basket—a basket grate, standing on legs upon the hearth, which is now familiarly known as the "Dog-grate." Fig. 83 illustrates a modern type of this grate, still possessing all its original faults, but having favour because of the handsome effect that can be had by its aid. A grate opening, an open hearth about 40 to 50 inches wide, by about 2 feet deep, is prepared, the side and back walls and the hearth being tiled in as fine a manner as the arranged cost will permit. Recently the side walls have been splayed, as the illustration shows, but usually the opening is more square. The dog-grate is then stood in place, and the "fixing" is complete.

The dog-grate affords comparatively little heat for

the fuel burned, and, although the appearance is striking, the method of fixing quite commonly causes smoke trouble to arise. It is not down-blow, but what appears to be a want of up-draught, for there occurs a slight oozing of smoke from beneath the

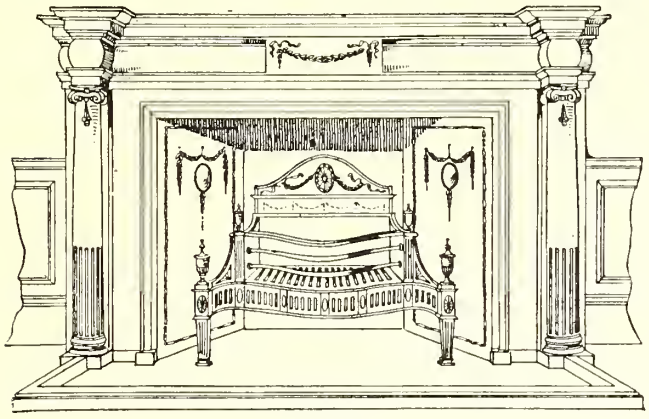


Fig. 83.

mantel frieze, while the general volume of smoke ascends the chimney very sluggishly. The cause of the trouble is the large open air space above the fire, which has the effect of impeding the free passage of the smoke. One remedy for this is the same as that adopted with the old open range (which suffered with the same trouble from the same cause), this being the use of a "blower." With the range the blower consisted of a flat tinware sheet, extending across the upper part of the opening, in front, with a view to causing all air entering the chimney to pass nearer to the fire and so be warmed. With the dog-grate the blower, when needed, is arranged in the same way, but it is made of glass, either bevelled plate or leaded glass, in a brass frame. A better remedy, however, can be found in the use of a hood or canopy, with a short flue extending from it, as shown in Fig. 84. An ornamental brass or copper trumpet mouthed hood comes down over the fire to receive the smoke, while its upper end goes through a sheet-iron plate which closes the chimney across, as shown. Under these conditions a dog-grate suffers no more by sluggish draught than an ordinary grate, yet it may stand in a clear tiled opening as a dog-grate is required to do.

It is needless attempting to show the various degrees by which the fixed grate came into use, but it may be of service to show what, until recently, were the ordinary kinds of room fireplaces, if only to describe their faults. Fig 85 shows one of the earlier kinds—a hob-grate, which might be described as a dog-grate fixed between a pair of hobs. It possessed all the faults of the dog-grate (as will be seen at a glance) without the one advantage of the good appearance.

Following this came the "register" grate (Fig. 86). The improvement in this lies in the size and position of the chimney opening, this causing all air to pass close over the fire before entering the chimney, to the exclusion of all cold air getting there. According

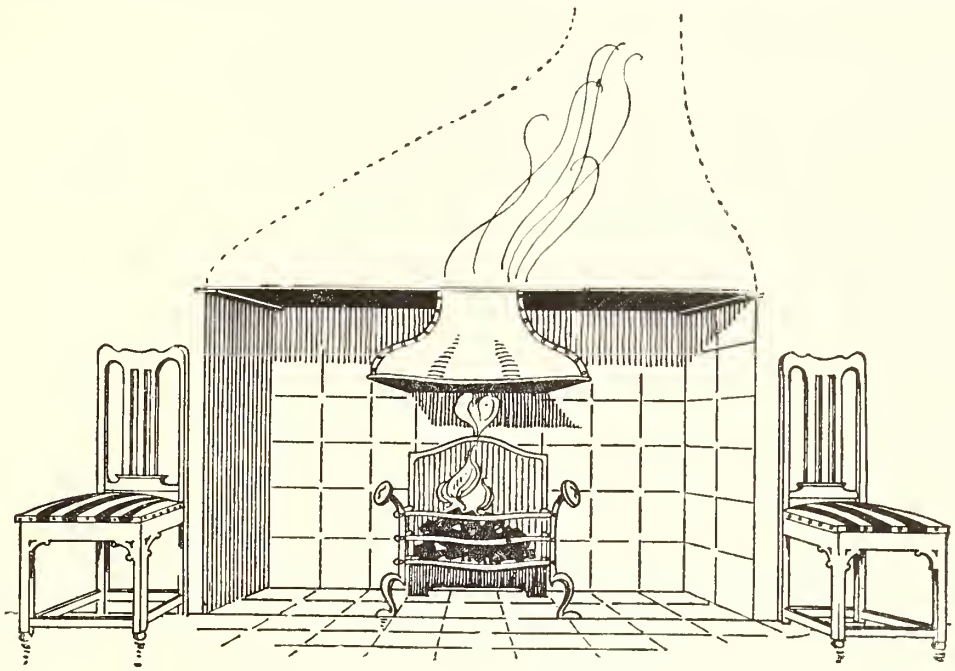


Fig. 84.

to old books dealing with this subject, the plate, which is shown closing the chimney opening, could be "set" to remain open to any desired extent, by means of a rod and knob coming through the front. This could be operated at any time while the fire was burning. Later, and within the writer's recollection, the plate had

a loosed notched quadrant attached to it, by which the plate could be fixed open to any required extent, this being done while the fire was out. These arrangements undoubtedly gave the prefix "register" as part of the name of the grate, but of late years the plate has had no setting device, and it rests open and useless all the time. The setting of the plate, while the fire was alight, was of real use, as, after a bright fire had been established, the partial closing of the plate checked combustion and caused a noticeable increase in the heat projected into the room. It had to be used discreetly, for if nearly closed when the fire was bright, and left so when the fire was replenished with fresh coal, the room would be filled with smoke in a brief time.

About twenty-five years ago it became recognised that the fire grate consumed fuel too wastefully, and

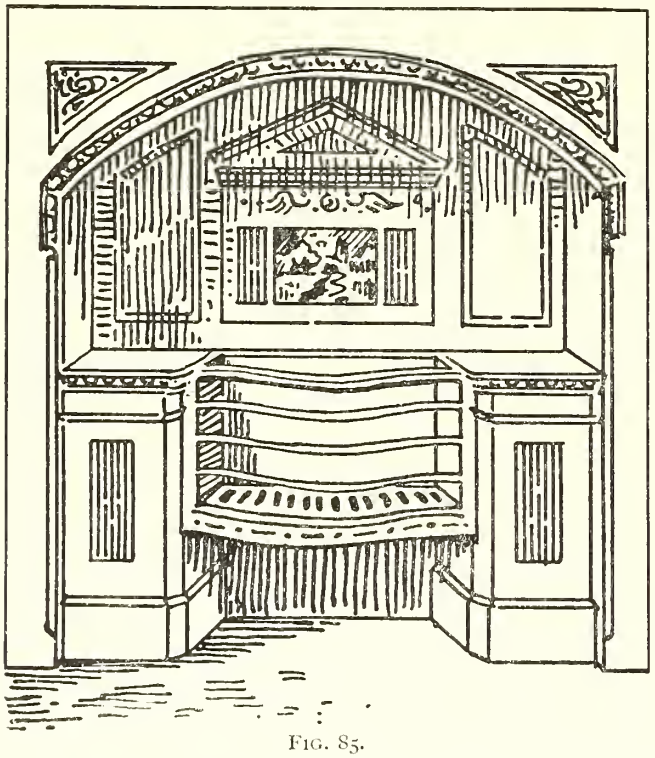


Fig. 85.

the "slow-combustion" grate became famous. The best known of these had for its chief feature the lowering of the fire-box down to the hearth, while the bottom of the fire was formed with a solid firebrick slab. This was a distinct improvement, and no maker has since reverted to the high fire. The solid firebrick bottom gave the required degree of slow combustion, but it had two drawbacks. Firstly, it made the fire always slow, whereas it was only required to be so when burning brightly. Secondly, the ashes and the débris of the fire remained in the fire-box and collected until, with poor coal, the fire appeared to be more ashes than anything else. To rake the fire out was not to be thought of, consequently by evening time, when the fire should look its best, it was very unsatisfactory.

About this time Dr. Pridgin Teale, in a lecture which he delivered relating to economy of coal in house fires, laid down some excellent rules, a summary of which is as follows:—That except for the front bars and bottom bars there should be no metal in contact with the fire. The back and sides of the fire-box (composed of firebrick slabs) should, above the level of the fire, lean or slope over the fire and not slope away from it. The lean over of the back should be at an angle of 70 degrees; the sides much less. The depth of the fire, front to back, should not be less than 9 inches. The sides of the fire, all the way up, should be an angle from front to back of 45 degrees. The bottom of the fire should be a grating, to allow the ashes to fall through, but there must be a plate to close in the front opening of the ash pit. This plate was designated

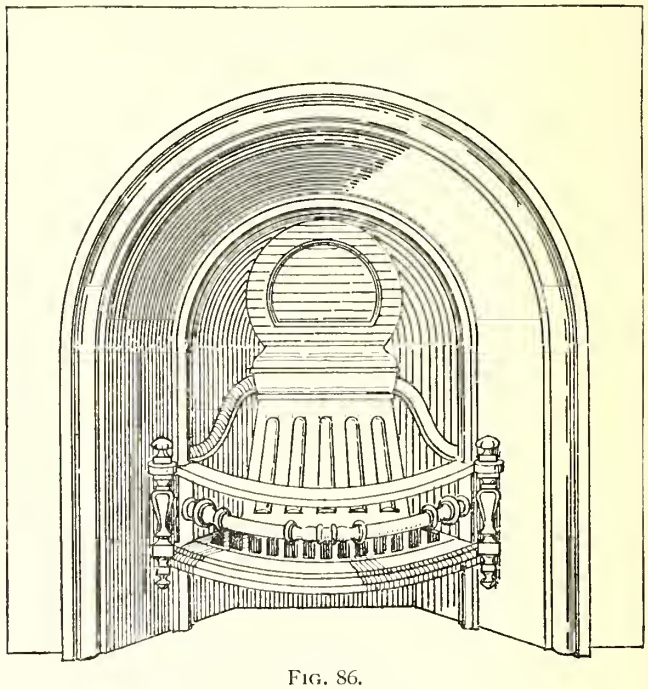


Fig. 86.

an "Economiser," as by its use air was prevented from passing through the bottom bars and a slow-combustion fire resulted.

Fig. 87 shows a fireplace made on Dr. Teale's design, and although the sketch suggests little that is attractive, the effectiveness of the grate is beyond question. Realising that the heating efficiency of a grate must lie in the extent to which it radiates heat (whether to warm occupants or the inanimate objects and parts of a room), it was natural to seek for this in the form or arrangement of the firebricks. To avoid the use of iron in every possible way is essential, as iron is not only a rapid conductor of heat, but its conductivity (in grates) keeps the fire, in contact with it, in a semi-dead state. The form of the back brick, the section of which has been likened to a "dog's hind-leg," has two distinct effects in heat distribution,

as it both radiates and deflects heat rays. Fig. 88 will serve to describe this, the solid lines representing heat radiated in direct lines downwards from the intensely hot brick; while the broken lines show the deflection or rebounding of heat rays that are projected from the top of the glowing fuel. Very brief experiment will show that heat rays will strike and rebound from a surface (at an angle according to that of the surface) in the same way as rays of light can be deflected by a polished surface. Thus the overhanging brick affords heat in two ways, while, in addition, its leaning over the fire causes it to become intensely hot, so much so as to burn quite clean and be nearly as hot and effective as the glowing fuel beneath it. Compared with the old Register grate, it may be fairly computed that this brick alone has increased effectiveness quite four times or more. The heat rays from the brick

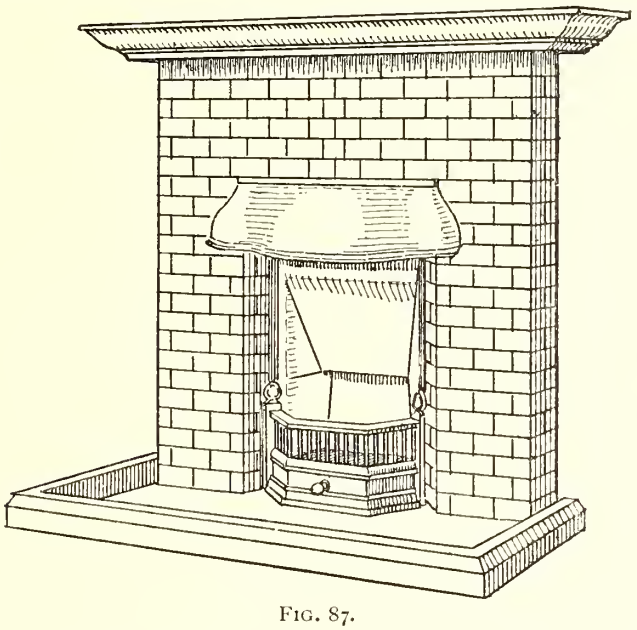


Fig. 87.

(the solid lines) being projected towards the floor is a most effective feature in itself.

The design of the brick suggested by Dr. Teale has been departed from in Fig. 88, so far as that part hidden by the fire is concerned. The brick is shown coming forward at the bottom, and having quite a narrow grating between it and the front bars. This is an improvement that has been introduced with the idea of lessening the bulk of fuel at the back bottom corner, where it serves no specially good purpose. The original Teale brick had a quite vertical back surface in the fire-box.

In arranging that the side firebricks of the fire-box, and particularly above the fire, be at a 45 degree angle, the intention was to project radiant rays into the room, to the right and left at a 45 degree angle, as Fig. 89 will show. This result is very effectually obtained.

In Fig. 88 will be seen, in section, the "Economiser." This is an ornamental casting that is made to rest on the hearth and come closely against the bottom bar of the front grating. It is simplicity itself, but its effect is all important. As already stated, slow combustion is obtained by preventing air from passing through the bottom of the fire. This not only reduces the rate of combustion, but it also prevents the bottom of the fire

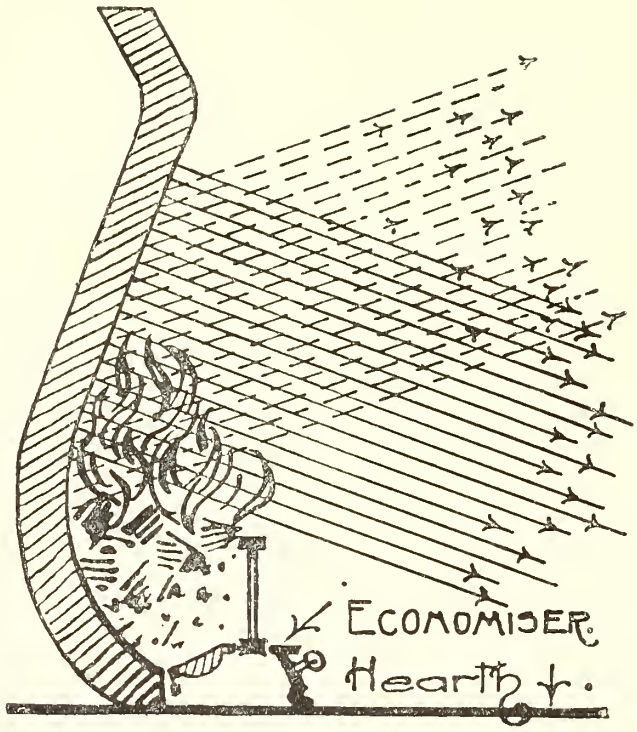


Fig. 88.

being a bright glowing part for no good purpose. In obtaining the slowness, however, it is important that the fire shall not always be slow, and to hasten combustion, when needed, the economiser can be drawn out. It is a most effective detail, and figures, either directly or indirectly, in all modern grates.

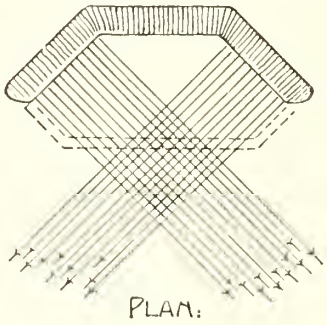


Fig. 89.

The grate having the largest number of novel practical features in it is that made by the Eagle Range Company. This grate has the Teale improvements (as practically all grates now have), but in addition there are three pairs of hinged doors in the front that can be operated to produce certain desired

effects. Fig. 90 shows this grate, and the illustration A represents it with all doors closed. This is to afford a good appearance in summer when the fire is not in use.

B shows the lower pair of doors open, which makes the grate a stove for the time being, with a fierce draught to hasten the fire, when first lighting or whenever it may need reviving. C shows the grate as ordinarily used when the fire is in a normally bright condition. D shows the lower doors only closed, and this is the most novel if not the most useful feature of all.

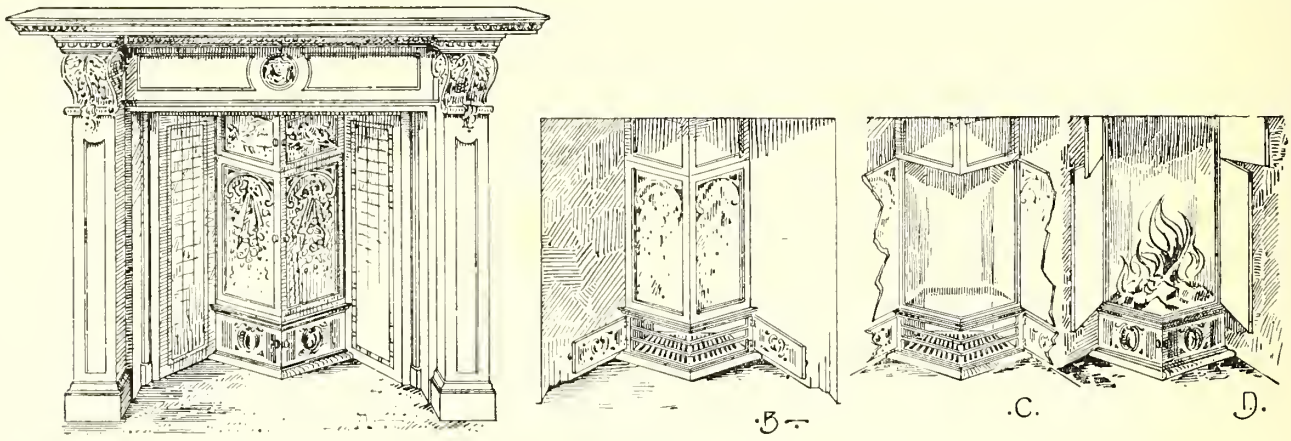


Fig. 90.

A considerable number of years ago Dr. Arnott introduced a grate which amounted to being a fire-box sunk in the hearth, or equivalent to this, so that no air came to the fuel except at the top. While in this state the grate afforded a little heat, but the remarkable result was that the boxed-in fire, instead of going out, was found to keep alight a great number of hours without attention. When warmth was needed it was only necessary to uncover a part of the front of the fire (which he did by winding the fire-box up) and the fuel quickly commenced to burn briskly. This is the principle and effect of the Eagle grate when arranged as shown at D. The makers state that the fire can be kept alight for 14 hours without attention, but the writer has had it do so for 18 hours, and at the end of that time the fire was red and of quite a good appearance. It seems as if combustion could be stayed, as the fire was not made up above the top front bar, the fire-box not holding more than a few small shovels of coal.

Of recent years there has been a tendency to do away with the front bars of grates, so that no barrier, however slight, shall exist between the fire and the room. Impetus was given to this by the introduction of the Well-fire, an illustration of which is given in Fig. 91. This, as will be seen, much resembles a Teale grate, but without front bars, and it has a raised hearth, with an air flue in it, as the economiser. The raised hearth is not needed when the "well" can be sunk in the ordinary hearth, but this is not always possible on floors above the ground floor. If the preceding pages have been read it will be readily seen that the grate has a high effectiveness, and, to the majority, the piled fire and absence of bars has a pleasing effect.

The success of the well-fire has brought into existence a number of grates designed to work without front bars, and now commonly designated sunk or basket fires. These do not necessitate a raised hearth, though the effect of this is sought after. Fig. 92 shows such a grate, one of Barnard, Bishop & Barnard's. The economiser in this case is made as a hit-and-miss ventilator, so that in regulating the speed of combustion the economiser itself need not be bodily shifted.

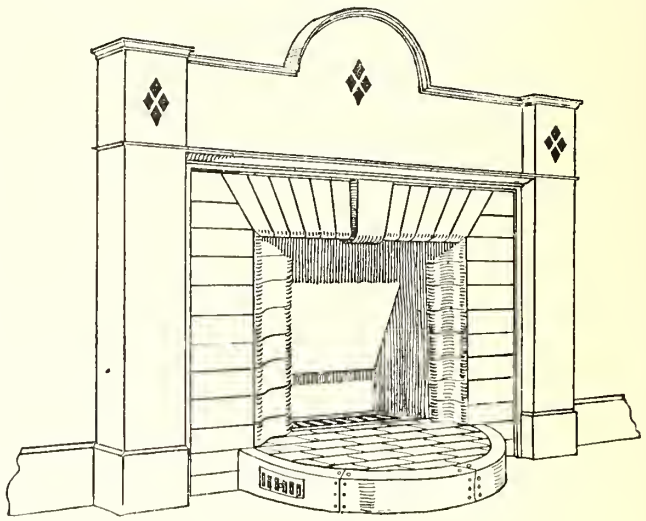


Fig. 91.

Fig. 93 illustrates a grate of similar character, but having a front bar which can be raised to afford support to the fuel when a large fire is needed; or lowered, as illustrated, to form a trivet; or it can be pushed back beneath the bottom bars and so make the grate barless. There are now numbers of such grates on the market, and the few examples given are merely to afford an idea of the progress that has occurred in this industry.

A grate worthy of notice, as affording all the effective appearance of the dog-grate but without its faults, is the "Nautilus," an example of which is given in Fig. 94. This grate is intended to stand in a tiled opening, but

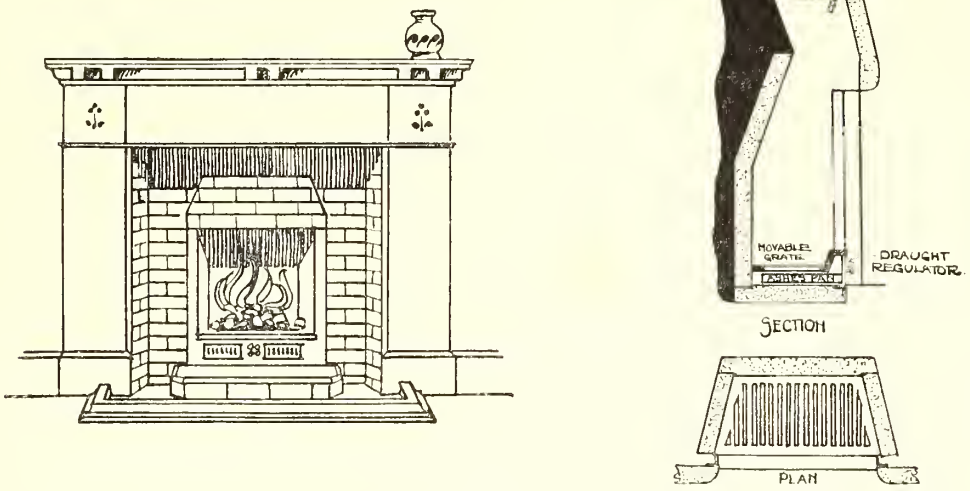


Fig. 92.

instead of the smoke getting away up the open mouth of the chimney above, this latter opening is closed and the grate nozzle (at the back of the grate) is connected to a flue brought down in the wall at the rear. The

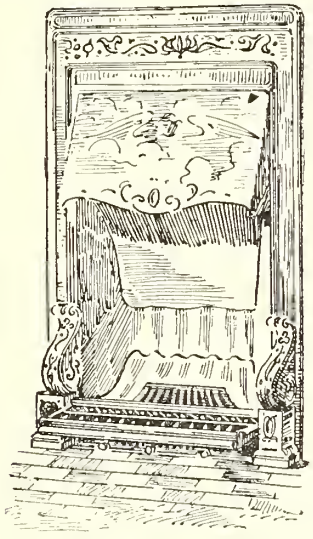


Fig. 93.

grate being on wheels is to admit of its being drawn forward when the sweep has to clean the flue and chimney.

Ventilating Grates

It is somewhat surprising that the ventilating grate has not come into more general use, remembering that, apart from the question of ventilation, it largely obviates that fault of the ordinary grate, the cold draughts induced. It is quite recognised that with every grate there has to be a chimney, and that this chimney extracts air from the room in great volumes (doing excellent work as an extract ventilator in this respect). This being so, a moment's thought will show that the extracted air must be replaced from—somewhere. In the ordinary way it comes through

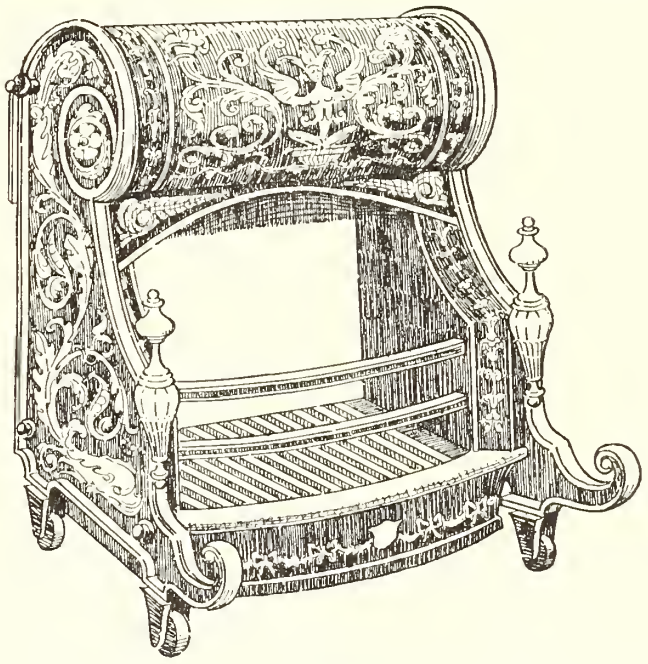


Fig. 94.

doorways, if the doors are open, otherwise through crevices around doors and windows. In practically every case it comes from a cold source and is then known as a draught, which everything possible is done to exclude. The correct thing would be to encourage

this air movement, as the chimney needs a good supply and the occupants of the room cannot have too much air for health, if it is not cold enough to lower temperature and vitality seriously.

The ventilating grate meets this condition very successfully, as it provides for a good sized clear hole being made in the room wall, and the air coming through this aperture is warmed, and consequently does not manifest itself as a draught. The provision of the hole, it will be seen, instantly checks, often quite disposes of, the draughts from other sources, for it follows that air will not flow through circuitous and

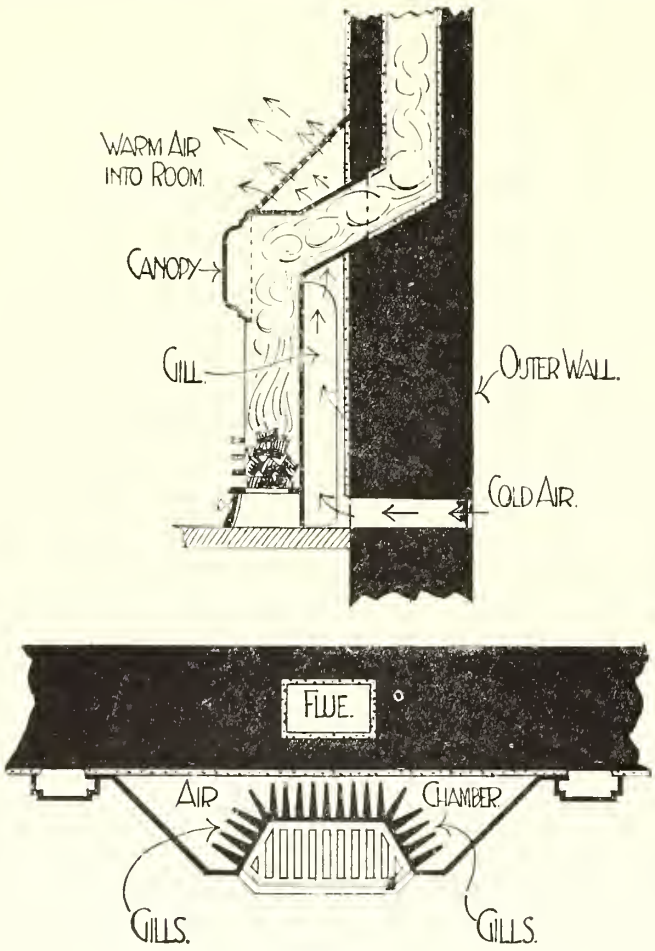


Fig. 95.

confined ways, if all that is needed can come direct through a hole in an outer wall. This can be tested by opening a window, which instantly stops the draughts through door crevices. The warming of the in-flowing air does not impede its flow to a noticeable extent, as will be seen by Fig. 95, which shows the chief parts of a ventilating grate in plan and section. The grate is of a type that projects on to the hearth (a type that is too much neglected), and around the soundly made fire-box is an air-chamber which is air-tight except for the inlet aperture at bottom and the grated sloping casting which forms the top of the air chamber. The gills forming so many air flues and the metal being hot, the air cannot get through and escape into the room without being agreeably tempered if not fully warm. The peculiar effect obtained with gilled surfaces, the extension of surface so obtained, and the reduction in the general temperature of the surface, has been already spoken of.

Perhaps the best known ventilating grate is that

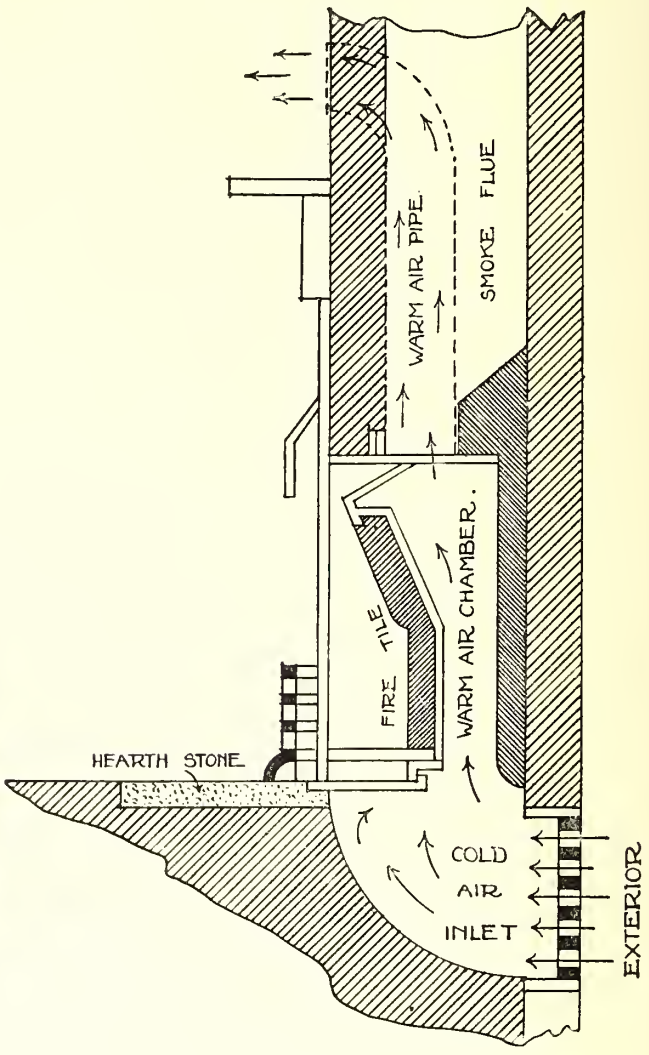


Fig. 96.

made by Shorland of Manchester, a section of which is given in Fig. 96. This is a grate interior with air-chamber behind, and the special feature is the arrangement for discharging the air. Instead of coming through a grated panel in the air chamber, a nozzle is provided for a warm-air duct to be taken vertically and discharged at a high point in the room wall as shown. This agrees with the generally accepted opinion that warm air should be discharged high, and vitiated air extracted from a low point, the openings for both to be on the same wall, as explained in the Chapter on Ventilation.

Grate Fixing

It may be said that there are but two things that are essential in grate fixing, one being to fill in all space around the back of the grate solidly, the other to see that the fixing is air-tight. In fixing what is called an "Interior," this being the fire-box and firebricks only (the sides being built up with tiled splay fronts), there is little difficulty about filling in the back solidly,—in fact, it could scarcely be done otherwise; but with grates which have ironwork extending to the mantel-piece on each side (as Fig. 86, for example) the filling is not so easily done, and is consequently often neglected. It must be done, however, even if it necessitates dropping in mortar (lime) concrete a trowelful at the time. When filled, the upper surface is benched-up smoothly so as to afford the least possible lodgment for soot.

In making the fixing air-tight, the filling-in just described serves to do this if properly done; but in any and every case there must not be any openings around the grate by which air can be drawn into the chimney without passing over the fire. This is essential. With the majority of Register grates a very brief examination usually shows an opening along the top edge (under the mantel-frieze), if not up the sides also, and this cannot fail to make the grate work less effectively than it would do. In frequent cases the grate works very badly, due to this.

All grates, whenever possible, should be secured to the side or back walls of their openings by iron cramps. This is a much neglected detail, and, in the case of interiors, the fixing soon gets into a loose and bad condition, the grate itself sometimes working forward as much as an inch on to the hearth

Laying Tiled Hearths

In ordinary apartments having wooden floors the hearth space is given a wooden border, as in Fig. 97, and it is very desirable, if it can be arranged, that the dimensions of this border be made to agree with the tiles, instead of cutting the outside tiles (or thickening the cemented joints) to suit the border. Supposing, however, that a tiled hearth has to be laid in an existing border, then, for a narrow space (between the tiles and border) probably a wood slip can be used, or a slip tile of the same colour. No work can be worse, or look worse, than that in which thick cement joints are made between the tiles to enable them to fill out a space. In cases where the tiles, when "offerred" down, prove to be a little too wide, then, if a tile cannot be abstracted and narrower slips substituted, the outside tiles must be cut. If a quite narrow strip has to be removed a keen chisel is used, care being taken to make the first cut on the glazed side of the tile; but if a $\frac{1}{4}$ inch or more has to be taken off, then a pair of carpenter's pincers may be employed. A very good cut can be made by nipping pieces off a tile, and breakages are reduced to a minimum when tiles are treated in this way. If very smooth edges are required they can be finally rubbed down on stone.

A hearth bed is first laid in cement and sand (one and one), and this is made true with a piece of wood known as a rule. This is illustrated in the lower part of Fig. 97, the ends being rebated so as to rest on the wood border of the hearth space. If it is thought that the cement will set too quickly, it can be killed by allowing it to nearly set, then breaking up the mass and remixing with water.

The hearth bed having been made level and true, at a depth below the wood border which will bring the tiles up level when laid, the tiles, having been previously soaked in water, are next placed in position. No cement is spread on the tiles; it is sufficient if they have their bottom surfaces dipped in some liquid cement. No cement should come on the sides between the tiles, and a visible cement joint is quite wrong. The middle tiles at the front should be laid first, an exact centre being obtained at the start. When all are laid a piece

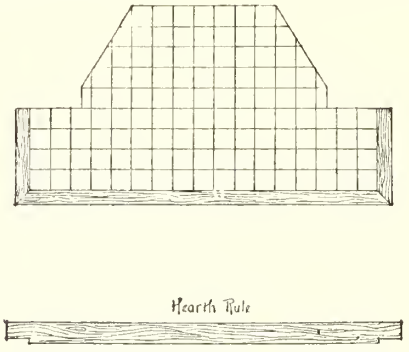


Fig. 97.

of stout flat board is placed on the tiles, and this is gently beaten so as to make all level. A further effect of the beating is to bring up a little liquid cement between the tiles, which is not objectionable, as it only fills spaces which would otherwise be hollow. A little dry cement can be rubbed over afterwards to fill any remaining spaces. The final task is to clean out any visible cement at the tops of the joints, this being done with a pointed piece of wood and a cloth.

Stoves

It is not intended to speak of the ordinary type of stove, which is merely an iron casing lined with fire-brick, as it possesses no special features worth describing. Description will therefore be confined to ventilating stoves, stoves which are made with air-warming passages within them, and are used for air-warming in some way. Stoves of this kind are largely used for hospital and institution work, and for the waiting-halls of railway stations, etc.

In Fig. 98 is illustrated a ventilating stove, the air-warming surfaces being extended, firstly, by the gills shown within them; and secondly, by the smoke flue

being diverted down between the air passages, as will be seen. Provision is made, by means of a sliding damper, for the smoke to pass direct from fire-box to the flue nozzle, if required. It will be noticed that the warmed air is discharged through grated sides as well as at top. This is a stove in the strict sense of the word, the fire not being visible, and the fire-box receiving a charge of fuel sufficient to enable it to last for several hours without attention.

In Fig. 99 is shown a stove that could be described as an independent open grate, the vertical plate appear-

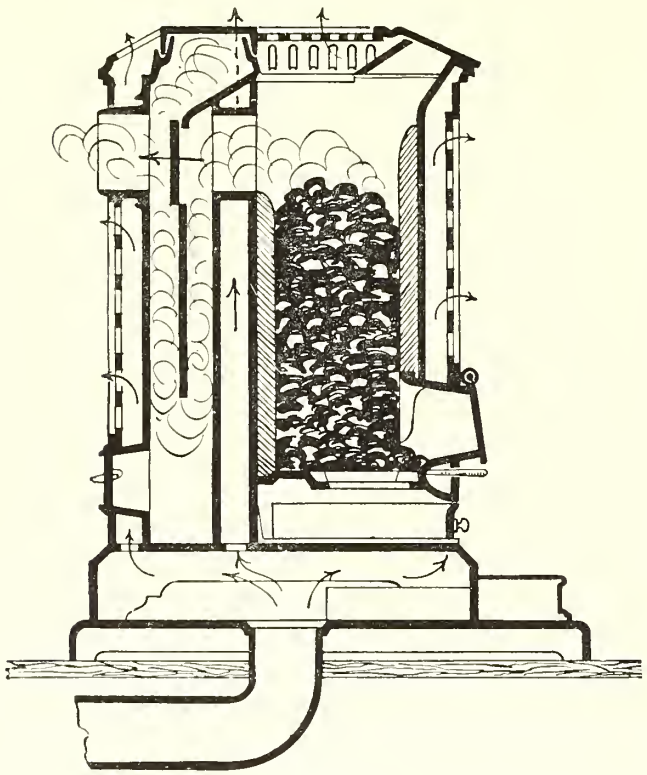


Fig. 98.

ing to rest on the top front fire-bar is a blower for drawing up the fire, when required; at other times being removed to expose the fire to view. The air-heating surfaces are chiefly tubular in this case, passing to and fro across the heated flue-way.

In Fig. 100 is shown a stove similar to the last, but in double form, the two fires being back to back. The special feature in this illustration, which will bear describing, is that of the underground invisible flue-ways. In the majority of cases large stoves—certainly double ones—are placed centrally in the room or place to be warmed, and an ascending smoke pipe may not be possible or would be strongly objected to. In such cases the stoves are connected with a suitable brick chimney in the nearest wall, the connection being by underground flue. Needless to say, the floor must be of incombustible material, although the writer once saw an iron flue pipe carried through a wooden floor and run horizontally, suspended from the beams beneath, the whole being kept 9 inches from woodwork, as required by the London Building Act.

Underground flues should never be of less size than the flue nozzle of the stove, and provision must be made for sweeping them. To secure efficiency with an underground flue, the descending part should never exceed 5 feet, and the whole descending and horizontal portion should not exceed one-third the height of a perpendicular chimney to which connection is made. When an underground flue is of iron, or loses heat at all fast; or if it is unusually long, it will be found necessary to use a "pilot-stove" at the base of the vertical chimney to start the draught when the fire is lighted, or whenever the flue has been allowed to cool down. This stove can be of any close-fire kind, in small size, and connected so that when the draught is established it can be shut up air-tight and not prejudice the working of the other by being equivalent to a leak or a hole in the chimney. It is not always necessary to use a stove for the pilot fire. In many cases it is sufficient if a soundly fitted soot door is provided, this being opened to allow of a good handful of lighted shavings being thrust in to start the draught.

Whatever kind of warming stove is being fixed, but particularly those with underground flues or working under any unusual condition, the flue pipes, whether of iron or earthenware, or built of brickwork, must be absolutely air-tight at all points. There are extravagant ideas regarding chimneys—as to the draught being improved if a slanting hole is made in the chimney, and things of this kind—but as the efficacy of a chimney is in ratio with its heat, it is important that cold air be prevented from entering. The rule—and it has been called a golden rule in stove and range fixing—is to cause all the air which enters the chimney to first pass through the fire-box. The observance of this rule often causes the draught to be very strong, but this is distinctly better than a draught that is too weak. There are always legitimate means of controlling the draught in all fuel-burning appliances, therefore no excuse exists for leaky flues. Such leaks are an index to ignorant or careless work.

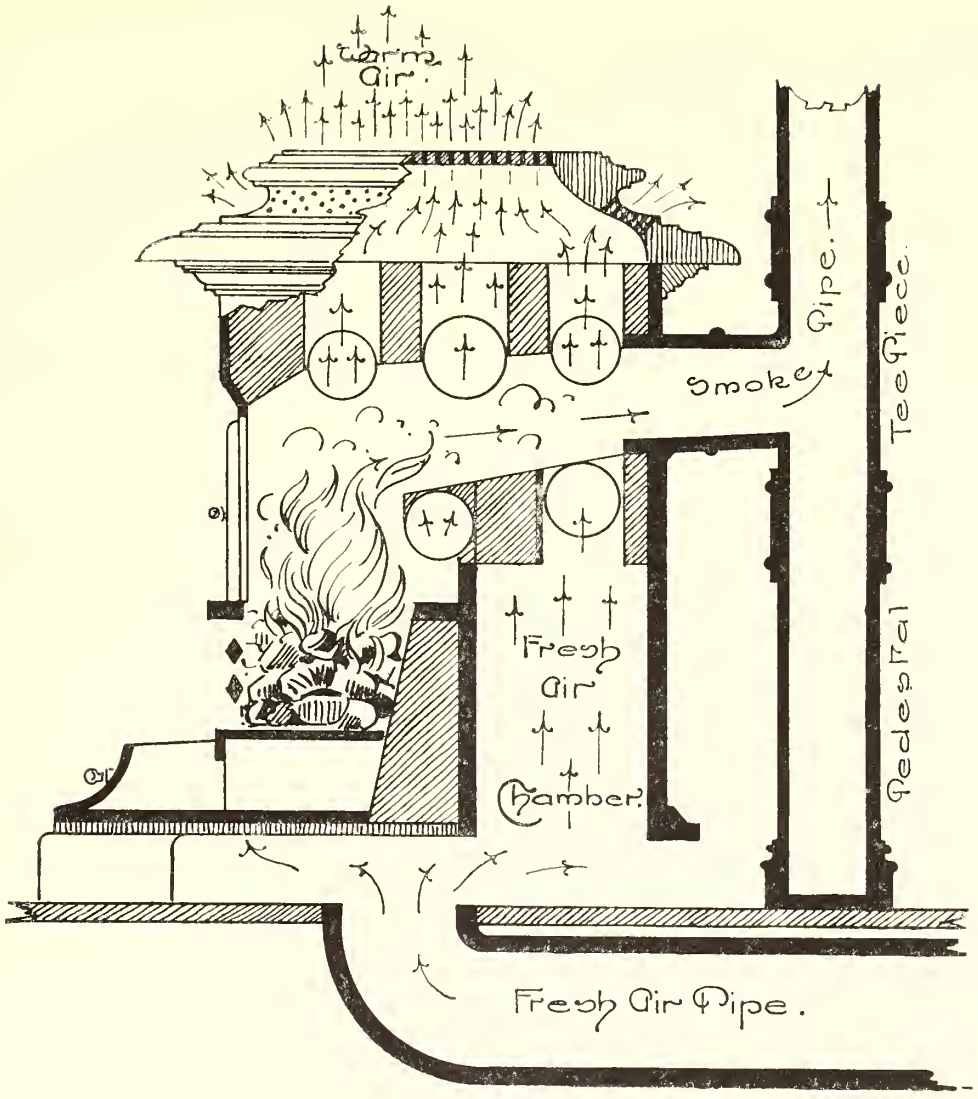


FIG. 99.

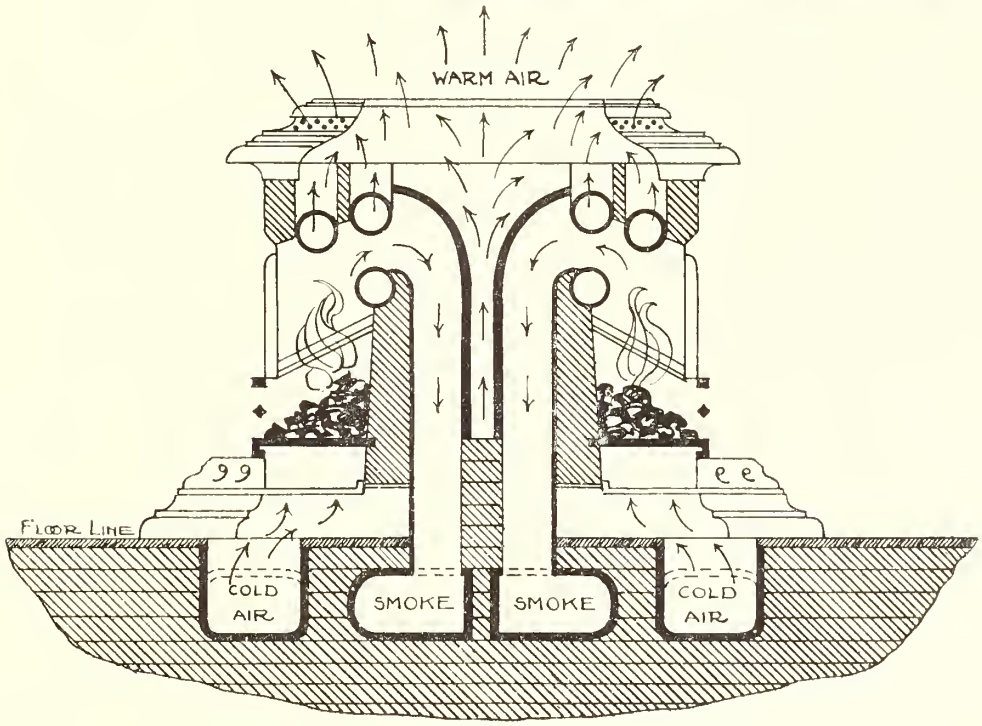


FIG. 100.

CHAPTER X

GAS-FITTING

(Contributed by W. Noakes)

Street Mains are generally laid in by the local Gas Company or their contractors, and are invariably cast iron. The size is, of course, in the discretion of the Gas Company, who provide as a rule for any estimated growth of the district by laying in a main of sufficiently large size against an increased consumption of several years ahead. The method of jointing usually adopted is the ordinary socket and spigot joint run with molten lead. The usual thicknesses of cast-iron mains are as follow:—Up to 9 inches diameter, $\frac{3}{8}$ inch thickness of metal; from 9 to 18 inches in diameter not less than $\frac{1}{2}$ inch thickness; and over 18 inches diameter, $\frac{5}{8}$ to $\frac{3}{4}$ inch thickness of metal. Mains should be tested to withstand a pressure of not less than 110 lbs. per square inch.

Service Mains are sometimes of cast iron, as in the case of a large supply being required from the street main, but as a general rule the service from the street is of wrought iron, for it is not, as a rule, required over 3 inches diameter. Wrought iron in small sizes is much preferable to cast iron, not being so liable to fracture.

Where the service required from the street main is so large that a cast-iron pipe is used, the method of connecting the two pipes is as follows (see Fig 101). The fitter sets out on the main the length of the tee piece or junction which he has to connect, which we will assume to be 2 feet; he then drills one hole on either side of the length thus marked on the main, into each of which he inserts a rubber bag with a pipe attached. He then inflates the bags and thus stops the passage of gas through the piece of pipe that he wishes to cut out. By means of a chisel he then cuts round the pipe at the points marked on the main, and a sharp blow on the pipe between the cuts will break the piece out, leaving room for the insertion of the junction. There will be one socket end on the junction into which one end of the main will fit, and the other socket is made by means of a loose collar, which is equal in length to about two ordinary sockets. This collar is slid on to the main or junction before the latter is inserted, and then, when the end of the junction is brought into line with the main, the collar is fixed to both main and junction by means of a lead joint at each end taking care that the joint between the main and junction is in the centre of the length of the collar. If it be inconvenient to shut off the main for the length of time required for making the joint a by-pass pipe may be fitted by drilling and tapping two holes in the main beyond the holes already made for the wind plug. Into each of these a bend is screwed, and the two are then connected by means of a connector or a short piece of pipe, thus allowing a constant supply to the other part of the main during the operation described above; and although a reduced supply only is provided it is generally sufficient for the time being. The holes in main made for plugging off and for by-pass must be stopped permanently with iron plugs before the main is again covered up.

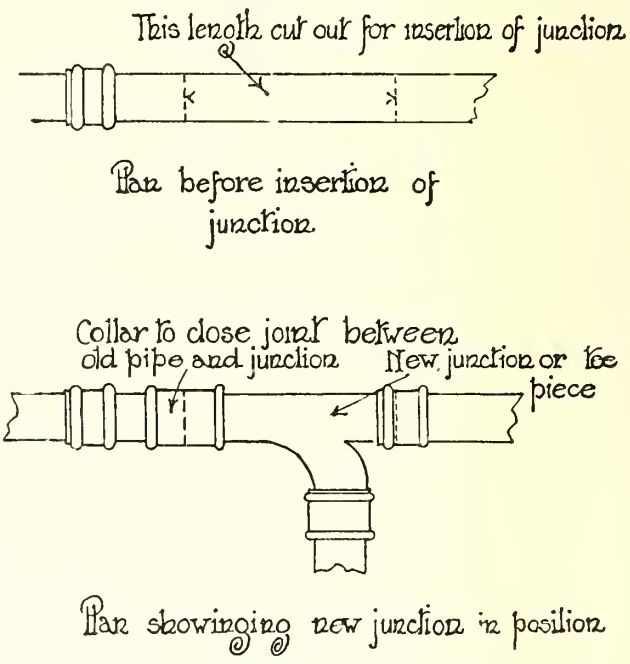

This length cut out for insertion of junction
Plan before insertion of junction
Collar to close joint between old pipe and junction
New junction or tee piece
Plan showing new junction in position

Fig. 101.

As stated previously, the service mains are generally of wrought iron, and the operation of connecting these to the main is rather different to the foregoing (see Fig. 102). In this case a hole is either drilled or cut in the cast-iron main, and this is then tapped to receive the thread on the service pipe to be connected. This thread should always be given a slight taper towards the end to ensure a proper tight joint being made. A thick paint consisting of red and white lead is used for screwed joints to assist in making the joint

quite sound. The common practice of using a considerable quantity of hemp in the joints to ensure their soundness is not to be commended, but the aim of the fitter should be to ensure perfect jointing by carefully cut threads, and by using as far as possible in one job the pipes and fittings of one maker only.

The laying of the pipes from the street into the house or meter house, after having made the connection on to the main, is very simple, being merely the forming of the ordinary screwed socketed joint. This is made in the following manner:—A socket, *i.e.* a short piece of pipe varying in length according to the size of the pipe, tapped at both ends to receive the external or male screw on the pipe, is screwed on to the end of the pipe already connected to the main, and into this is screwed the end of the next length of pipe, which also has a socket on its other end, and this operation is repeated until a sufficient length of pipe has been laid to reach to the meter house. This pipe is taken through the wall of the meter house, or whatever part of the building it is proposed to fix the meter in, and an iron-to-lead union is then screwed into the socket of the last pipe before reaching the meter; but before this union is put in the main service stop cock is usually

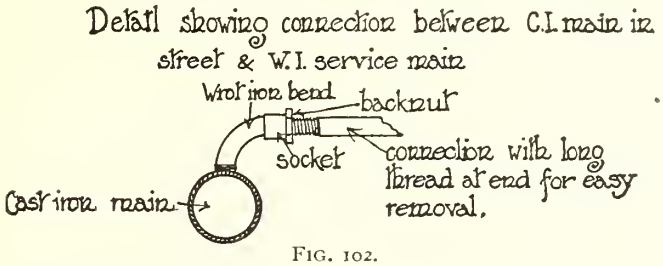
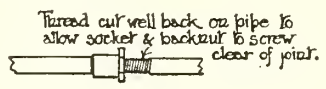

Detail showing connection between C.I. main in street & W.I. service main
Wrot iron bend
backnut
socket
connection with long thread at end for easy removal.
Cast iron main

FIG. 102.

fixed, as a means of shutting off the gas supply to the meter in case of repairs, removals, or for any other cause. This cock is provided and fixed by the local Gas Company, who also hold the key to it, and it should not be operated by anyone but a recognised official of the Company. It may be added here that while the Gas Company themselves generally run the main service and fit up the meter, except in the case of a very long distance existing between their main and the meter, they *always* put in the actual meter and the connections on the main side of the meter.

It should be borne in mind by the gasfitter during this stage of the work to make sure that no service pipe is too near the surface of the ground, especially where there is likely to be any heavy traffic, as it not infrequently happens that a steam roller or other very heavy vehicle strains and sometimes splits the pipe when passing over it, if it be placed too close to the surface. Although this is a matter under the direct supervision of the officials of the Gas Company, it is important enough to draw special attention to, as instances of neglect have led on more than one occasion to very serious and even fatal results.

To provide for the easy removal of a damaged or broken pipe, in any case where there is a considerable run of pipe or where there are several fittings, a CONNECTOR (Fig. 103) should always be inserted. This consists of a short length of pipe with the ordinary screw at one end and a longer screw than usual at the other, together with a socket and backnut. This enables the socket to be run back beyond the end of the pipe. The end of the pipe to be connected is then brought into line with the long screwed end of the connector, the socket being screwed back over the joint between the two pipes, the backnut being afterwards screwed hard back against the inside end of the socket. To remove a portion of the pipe at any time afterwards, it is only necessary to run back the backnut and socket

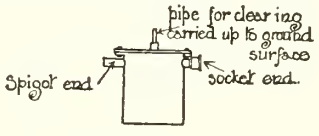


Detail of connector & backnut.

FIG. 103.

when the butt jointed ends of the two pipes are exposed, and either pipe can be easily unscrewed and taken out. Frequently considerable expense and trouble would be saved if this simple means of removal were provided more generally than is the case.

A slight inclination or fall should always be given from the service main to the street main, to allow any condensed water which may form in the pipes to drain away, and here attention may be drawn to the need of care being exercised in the work of laying in the service main. On no account should the pipes be laid so that they sag or dip. Great care should be taken that there is a continuous fall, for should a dip or sag occur it at once forms a place for the lodgment of water, and this



elevation of siphon box to receive condensed water.

FIG. 104.

will cause the lights to jump, and if the trouble be very considerable possibly form a trap which will stop the supply of gas passing through the pipe altogether. Where a fall cannot be obtained to the street main, the service main may be inclined to a siphon box such as is shown in Fig. 104, into which the condensed water can drain. This box must be easily accessible to enable the water to be removed from time to time by a siphon pump or other suitable means. Again, the service may be drained into a siphon formed close to the meter, as shown in Fig. 105 on the outlet side of the meter. This siphon is made up by means of a wrought-iron screwed tee piece, with a large centre branch into which a short length of pipe is screwed. The lower end of this pipe is filled with a screwed cap to enable

any condensed water which might accumulate there at any time to be drained away.

Meters.—The most generally used meter is that known as the Dry Meter, which is shown in Fig. 105, fitted up in position. Meters should be fixed as far as possible in a temperate position, and where the temperature is not too variable. The point to be observed in this respect is that gas contains more vapour at a low temperature than at a high one and the object should be to keep it as nearly as possible at the same temperature throughout the whole installation as when it leaves the main; for the lower the temperature of the gas falls, the greater the likelihood there is of trouble arising from water. The meter, too, should always be perfectly protected from the action of frost, and particularly should this precaution be observed in the case of wet meters.

The fixing of meter is generally done by the Gas Company, and the unions for the inlet and outlet are supplied by them attached to the meters; but should the gas fitter have to do the work he should not cramp

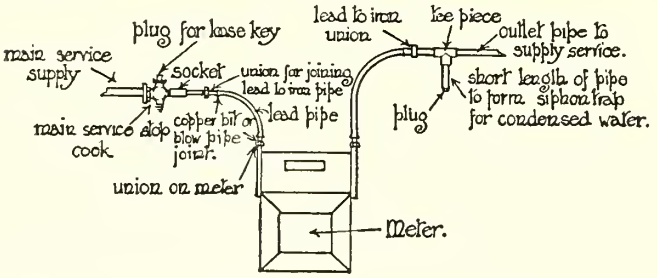

plug for loose key
lead to iron union
tee piece
outlet pipe to supply service.
main service supply
socket
union for joining lead to iron pipe
short length of pipe to form siphon trap for condensed water.
plug
main service stop cock
copper bit or blow pipe joint.
lead pipe
union on meter
Meter.
Details showing meter & connections thereto

Fig. 105.

the meter for room, but if possible allow sufficient space to enable it to be taken out at any time without disturbing any of the adjoining work; so that should it be required at any time to extend the system of heating or lighting a larger meter could be put in; and as the inlet and outlet pipes are of lead and easily bent and pliable, given sufficient room, this is not so expensive and troublesome a matter as it otherwise would be. The capacity of a meter is denoted by the number of lights it is calculated to supply. The accompanying table gives a list of meters which may be obtained from stock, and will be useful as a means of calculating for a meter.

Meters with a capacity exceeding 300 lights are not kept in stock by the makers, but are specially made to order. The makers as a rule give a guarantee with each meter for a specified time, usually 5 years.

The pressure at which gas is delivered into the mains varies from 2 to 3 inches head of water pressure. This is reduced considerably by the time it reaches the points where it enters the branches for the supplies to a building, where the pressure there would not be less than $\frac{14}{10}$; and this would probably be reduced to as little as $\frac{5}{10}$ by the time it reaches the burners.

The pressure decides the rate of the flow of gas in pipes, but for ordinary purposes it is not necessary to go into the velocity and volume of gas through a particular pipe, although the following is a formula by which this can be ascertained:—

$$Q = 1000\sqrt{\frac{D^5H}{GL}} \qquad D = 0.063\sqrt[5]{\frac{Q^2GL}{H}}$$

$G = 0.45$. $H = \frac{1}{2}$ to 1 inch.

Q = Quantity of gas in cubic feet per hour.
L = Length of pipe in yards.
D = Diameter of pipe in inches.
H = Head of water pressure in inches.
G = Specific gravity of gas.

As a general rule no pipe should be less than $\frac{3}{8}$ inch internal diameter, although one or two lights can be and often are taken off a $\frac{1}{4}$-inch pipe. A very important point to bear in mind in gasfitting is, that it is always better and more economical to have a good volume of gas at a lower pressure to supply a burner than to have a restricted area in your pipe and trust to the extra pressure to provide the amount of gas you require. With a fair ordinary gas supply the following may be considered a good practical table for the number of lights which can be safely taken off the respective pipes:—

To supply up to—

6 lights	{ internal diameter of pipe should not be less than }			$\frac{3}{8}$ inch.
12	,,	,,	,,	$\frac{1}{2}$,,
24	,,	,,	,,	$\frac{3}{4}$,,
48	,,	,,	,,	1 ,,
72	,,	,,	,,	$1\frac{1}{4}$,,
125	,,	,,	,,	$1\frac{1}{2}$,,
200	,,	,,	,,	2 ,,

The size of the pipes may be reduced on the higher floors of a building, as the velocity is greater at high levels than lower ones.

Table showing Sizes and Capacities of Dry Gas Meters.

Size of Meter	Height.	Breadth.	Depth.	Cubic Feet per Hour.	Size of Inlet and Outlet.
Lights.	Inches.	Inches.	Inches.		Inches.
1	12	$8\frac{1}{4}$	$6\frac{1}{4}$	6	$\frac{1}{2}$
2	$13\frac{3}{4}$	10	$7\frac{1}{4}$	12	
3	$15\frac{1}{4}$	$11\frac{1}{2}$	$8\frac{1}{4}$	18	
5	$16\frac{1}{2}$	13	$8\frac{3}{4}$	30	
10	$19\frac{1}{4}$	15	$10\frac{1}{4}$	60	1
15	$21\frac{1}{2}$	$15\frac{1}{2}$	$11\frac{1}{2}$	90	1
20	$23\frac{1}{2}$	$18\frac{1}{2}$	$12\frac{3}{4}$	120	$1\frac{1}{4}$
30	$26\frac{1}{2}$	$20\frac{3}{4}$	$15\frac{1}{4}$	180	$1\frac{1}{4}$
40	29	$22\frac{3}{4}$	$15\frac{1}{4}$	240	$1\frac{1}{2}$
50	32	$25\frac{1}{4}$	18	300	$1\frac{1}{2}$
60	34	$27\frac{1}{4}$	$20\frac{3}{4}$	360	$1\frac{1}{2}$
80	39	31	23	480	2
100	42	$32\frac{1}{2}$	$25\frac{1}{4}$	600	2
120	47	35	$26\frac{1}{4}$	720	2
150	$51\frac{1}{2}$	42	29	900	3
200	57	$42\frac{1}{2}$	30	1200	3
250	$58\frac{1}{2}$	$42\frac{1}{2}$	30	1500	3
300	$62\frac{1}{2}$	$46\frac{1}{2}$	$33\frac{1}{2}$	1800	4

CHAPTER XI

GAS LIGHTING AND HEATING

(Contributed by W. Noakes)

The ordinary form of flat flame burner is either a batswing, a slit union, or union jet, as shown in Fig. 106. These are perhaps the most used of all and are made by various firms, it being difficult to say which make, if any, is better than any other, while among quite the best is "Brays" patent. These flat burners are sometimes used in conjunction with an "economiser," which is really a second burner placed over the one which is screwed into the bracket or chandelier, as the case may be,—the principle of the economiser being to provide a greater volume of light than is obtainable by the use of the single burner alone, but at the same expenditure of gas. This result is obtained by using, for example, a No. 4 burner (which passes, of course, a less amount of gas than a No. 7), together with a No. 7 economiser, which gives as large a flame as a No. 7 burner. The action of the burner and economiser is somewhat on the governor principle; the gas has a smaller orifice to pass in the burner than in the economiser, and consequently the pressure is reduced after it leaves the burner outlet, with the result that there is more perfect combustion, while the flame is of the size of that from a No. 7 burner.

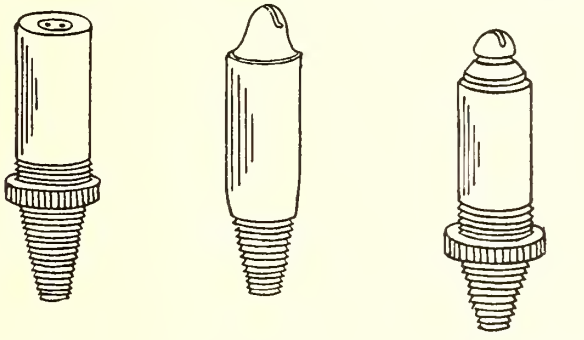


Fig. 106.

Another and probably better means of attaining the object for which the economiser is used, namely, to obtain the best light from the burner without a waste of gas resulting from any excess of pressure, is to use what is called a governor burner. This is really a miniature governor formed in the burner itself beneath the orifice for exit of gas. It should be borne in mind that extra pressure may be and often is caused by other lights being shut off, so confining the pressure to a reduced number of lights or burners, and need not necessarily be constant throughout the complete service. The most efficient burner of this sort to meet such cases is propably the Peebles, as shown in Fig. 107.

The action of this burner is as follows:—The gas enters the inlet of the burner where it is screwed into the fitting, and in the burner above the fitting is a float, which is so fitted that when there is little or no pressure the whole area of the inlet into burner is free for the passage of gas, but when the pressure becomes stronger the float is raised and partly closes or reduces the clear way through the inlet, so that the flow of gas is automatically controlled; for the higher the pressure the less is the clear way through the inlet for passage of gas, and *vice versâ*.

Fig. 107.

Another excellent burner on this principle is the "Helios," which is fitted with an aluminium float, and is adapted to act under any pressure from $\frac{5}{10}$ to $\frac{40}{10}$ inch. It is illustrated in Fig. 108.

There are several other forms of flat burners on the market, some of which have distinctive features, but their construction and principles are based on the foregoing examples.

The whole system of gas lighting has been so vastly improved within the last few years by the introduction of the incandescent burner that the great advance made has brought gas lighting within very measurable distance of electric light as a means of domestic and general lighting.

In fact, it is to be questioned whether electric light

is any improvement upon a really up-to-date and first-class gas installation; certainly, so far as expense goes, gas is so much the cheaper that with the recent improvements it is a doubtful policy to substitute the electric light for it.

The best known burner is the "Welsbach" of the "C" form, of which an illustration is given in Fig. 109. With about half the consumption of gas required for the flat flame burner it is possible to obtain nearly twice the amount of light by using a good incandescent burner.

The incandescent burner is constructed on somewhat the same principle as the well-known Bunsen burner. The gas is mixed with a certain proportion of air, which is admitted through the circular holes shown in the shield in Fig. 109, and when lighted produces a blue flame which gives out a considerable amount of heat, but until the mantle is placed over the flame the light is of such a nature as to be quite valueless. It is important that the burner should be so constructed that the air and gas will become thoroughly mixed in

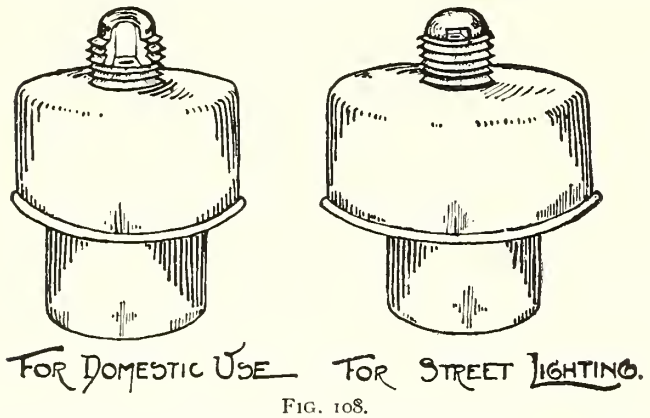


Fig. 108.

the correct proportions before ignition, for upon this the efficiency of the burner greatly depends.

The construction of the burner is not in the hands of the gasfitter, and every fitter and very many householders are now thoroughly conversant with its make and different parts, by reason of frequent handling in order to clean and replace broken or damaged mantles, so that it will not be necessary to give any further details.

The mantles are manufactured of ordinary knitted cotton, and, after being made, are washed in a liquid preparation of acid and ammonia, and afterwards saturated in another liquid, of which the chief ingredients are certain forms of very rare earths. They are then dried, and, after being subjected to a flame, are again steeped in further liquids and become ready for use. It is important that the light be applied at the top of the mantle when it is first placed in position, but full directions as to this are given with each mantle sold. The life of a mantle is somewhat variable, and it depends largely on the use to which it is subjected. If it be in a position where draughts may act upon it, or where it is subject to vibration, it will not last long; but with care and if removed from the conditions stated, it is reasonable to expect a good mantle to last for 600 to 700 hours.

After the Welsbach, the best known incandescent burner is the Sunlight, and the two are practically the same in construction, as indeed are all the various incandescent burners and mantles on the market. The

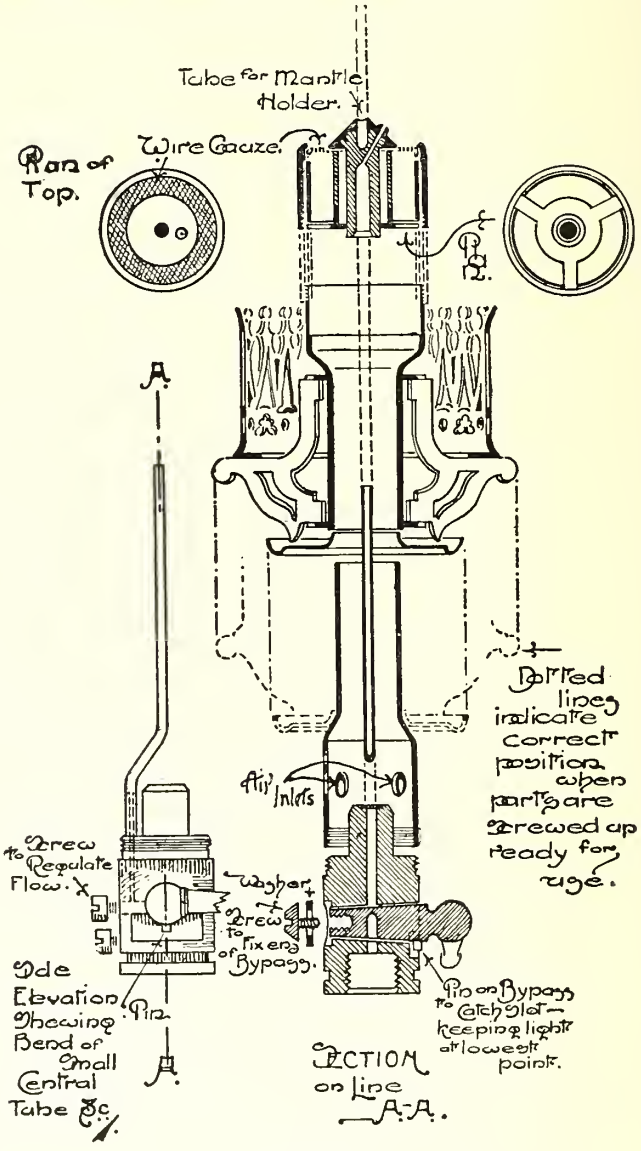

Tube for Mantle Holder.
Wire Gauze.
Ring of Top.
A.
Dotted lines indicate correct position when parts are screwed up ready for use.
Air Inlets
Screw to Regulate Flow.
Washer
Screw to Fixing of Bypass.
Pin on Bypass to catch slot—keeping light at lowest point.
Side Elevation showing Bend of Small Central Tube &c.
Pin
A.
Section on Line A-A.

Fig. 109

distinctive difference between the Welsbach and the Sunlight is that the former gives a whiter light than the latter, which is rather of a yellowish tint. The number of incandescent burners and mantles sold now makes it impossible to do anything more than briefly touch on one or two of the best ones.

A most effective form of incandescent lighting now coming prominently into use is the inverted burner, as shown in Fig. 110. The distinctive feature about this is that the whole of the constructional part of the

fitting and burner is above the light, and consequently nothing retards the illumination. The effect is exceptionally fine, and very closely resembles that of an electric-light fitting. It is excellent for use over a writing or drawing table, where the uninterrupted light and absence of shadows is of much importance.

It is usual to allow, when setting out for the lighting of buildings, 3 superficial feet of floor space per candle-power.

An incandescent burner is equal to about 40 candles, therefore to find the number of lights required for any room, first find the area of the room, and divide same by the space allotted to one candle multiplied by the number of candles in the burner. For example: area

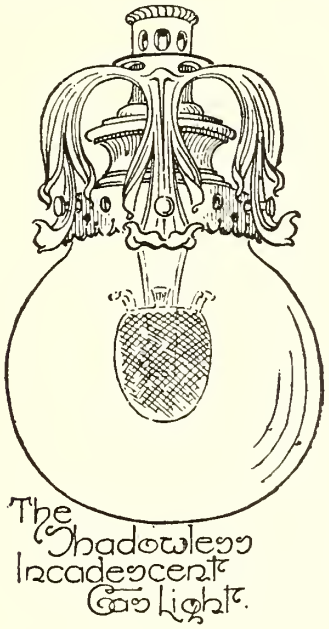


Fig. 110.

of floor, say, 720 square feet, $\therefore \frac{720}{3} = 240$ candle-power required; $\therefore$ 6 incandescent burners are needed of 40 candle-power each. To find the number of flat flame burners consuming 5 feet per hour required, divide the floor area by 50. As example: floor area $\frac{720 \text{ feet}}{50} =$ say, 14 burners; for the illuminating power of such burners is only about 8 candle-power each.

It is frequently found that the pressure in the service is variable, and while it is at one time perfectly even in the whole system, at another time it is excessive, which not only causes a waste of gas, but is apt to create fidgeting noises in burner stoves and fires. Further than this, if the pressure on a burner is very excessive, it not only wastes the gas, but the light obtained from that burner is not so good as if the pressure were properly and evenly controlled. Mention has been made of governor burners, and as far as they can be used they give excellent results; but in many cases, especially in fires and stoves, the burners are not fitted with governors, and to avoid waste in these cases it becomes necessary to employ a pressure governor. This is a fitting similar in principle to the burner governor, but of course in a much larger scale, as will be seen by reference to Fig. 111.

It is usually adjusted at $\frac{8}{10}$ to $\frac{10}{10}$ pressure, but can be set to whatever pressure may be required. It should be fixed on the outlet pipe close to the meter, and then governs the pressure perfectly regularly when properly adjusted. It is important that a governor be fixed quite level if it is to work satisfactorily.

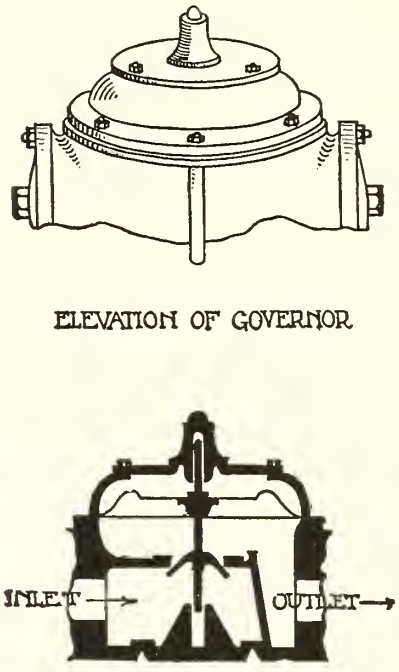


Fig. 111.

Gas Fires

The most common form of gas fire is that in which a burner is fitted to an existing grate, and the firing space filled up with asbestos or coral lumps. This is a very good form, but although the first cost is less than a specially made complete fire, the consumption of gas is higher to obtain the same result, and it will be found that the larger outlay in the beginning is generally cheaper in the end.

A point to be borne in mind in a fire of this kind is that the flue of the fireplace must be nearly closed, and only a small outlet left for the fumes, or there will be a great wastage of gas. A fire-brick back should be placed in the stove and the burner kept well to the front of the fire, to obtain the best effects. These types of burners are shown in Fig. 112, while a section of this sort of fire showing the arrangement of fire-bricks, etc., is illustrated in Fig. 113. A good example of a tubular stove is shown in Fig. 114, the section showing the arrangement of flues for the heating and discharge of the warmed air.

A stove suitable for use in shops, entrance halls, offices, etc., where it is not possible to provide a flue,

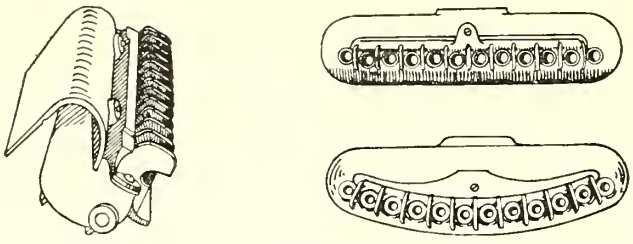


Fig. 112.

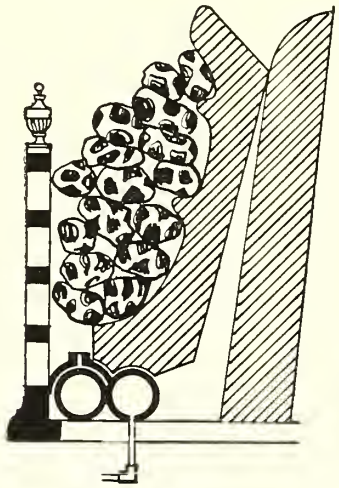


Fig. 113.

is shown in Fig. 115, "The Brighton." The products of combustion are condensed. A vessel is fitted under

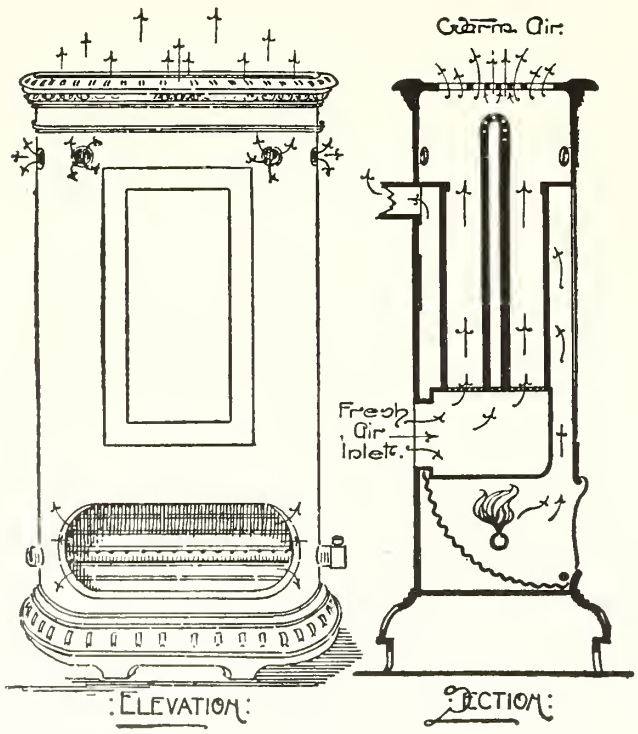


Fig. 114.

the stove which receives the product, and this should be emptied daily to be efficient. This is called a con-

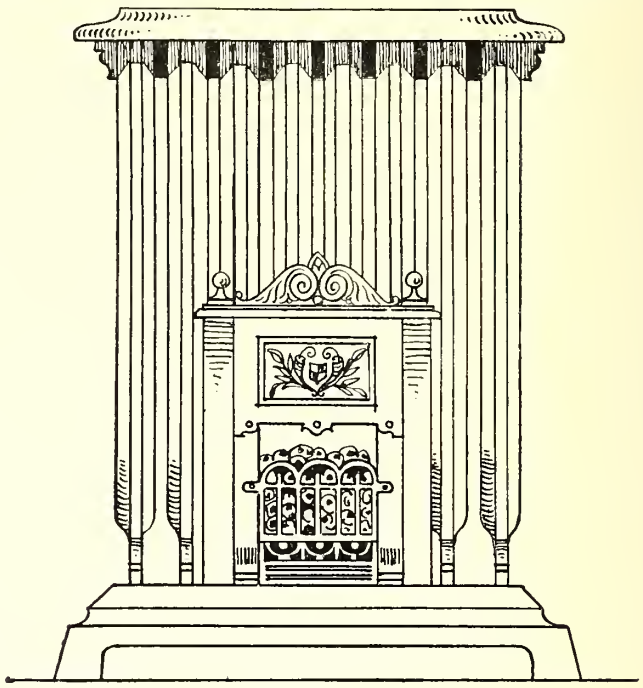


Fig. 115.

densing stove, and there are several others of a similar character.

A stove now being much used is the "Omega" (Fig. 116), which requires neither flue nor condensing chamber, the makers claiming for it that by the arrangement of the flues the fumes are completely sterilised and purified before being discharged into the room. This stove is portable, and can be supplied by special gas-proof flexible metallic tubes; and it may be stated

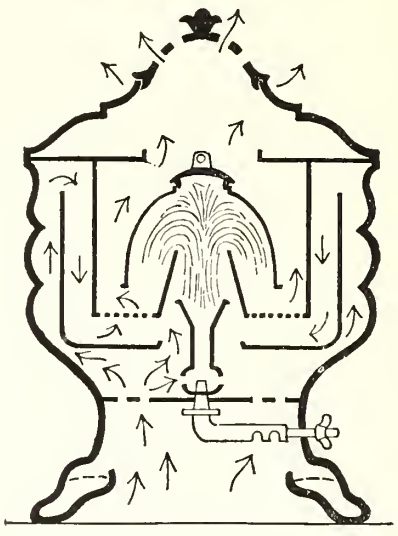


Fig. 116.

here that rubber tubes should never be used either for such stoves or for kettle boilers, etc. The principles

and construction can be easily understood from the section.

Another excellent application of gas for heating purposes is shown in the gas-heated steam radiator. This is to all appearances an ordinary radiator, into which is poured a small quantity of water by means of a valve and glass tube, as shown in diagram (Fig. 117), it being usual to keep the water level about the

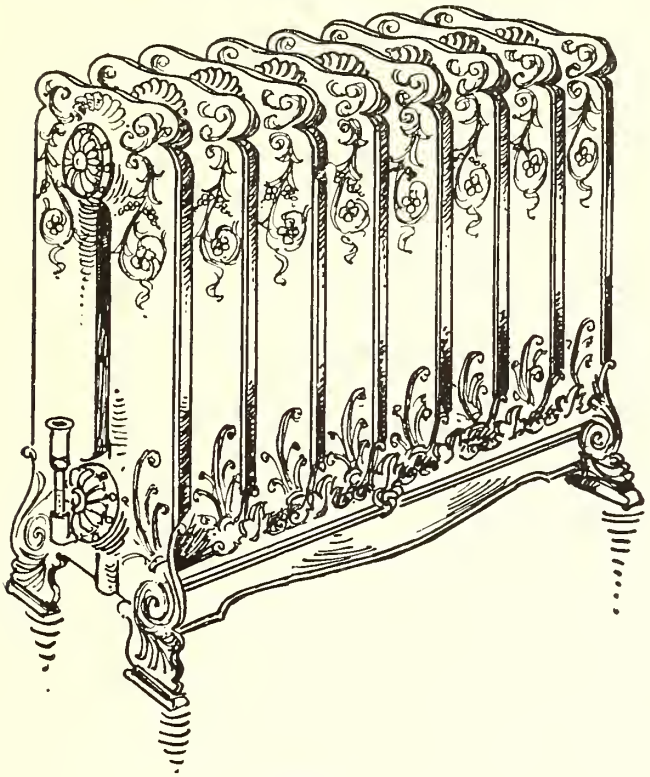


Fig. 117.

centre of the gauge glass. Gas heat is then applied to the water chamber, steam being thus generated, and the radiator is very quickly and well heated. This is really an excellent heater, and can be used without flues in any position that can be reached by a gas pipe.

On the same principle as the last example is the condensing gas radiator. This is very similar to the gas steam radiator, but there is no water in it at all, a condensing chamber being formed in the bottom to receive the products of combustion. This is also a good heater, with the advantage that there is no danger of the radiator being damaged by a careless person neglecting to see that the water vessel is filled, as is possible in the case of the gas steam radiator. An illustration of this is given in Fig. 118.

In conclusion, attention may be called to the great

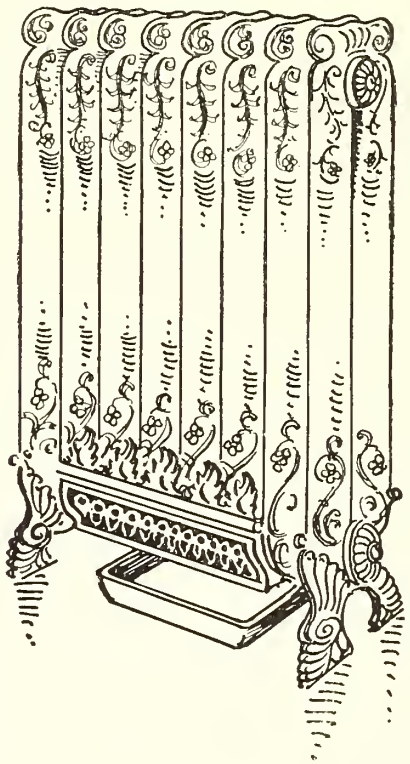


Fig. 118.

importance of testing the whole of the pipes and fittings in a building before they are plastered over or otherwise covered up. This is very frequently neglected by smaller tradesmen, but the expense involved in the purchase of a testing apparatus will frequently be saved over and over again. The writer has in his mind instances where this precaution has been neglected, and the expense and trouble involved in remedying the defects in these cases are oftentimes most serious.

CHAPTER XII

ACETYLENE LIGHTING

Acetylene lighting, like gas and electric lighting, is distinctly practical. It is now quite beyond the experimental or doubtfully new stage, and those undertaking this work are, or should be, able to give guarantees that will satisfy the most particular. In regard to expense, it can be worked out, theoretically, that acetylene costs the same as coal gas at 2s. 6d. per thousand for a given degree of illumination, but this figure fails in practice when allowance is made for the several extra small expenses and waste that are experienced. If the comparative cost is raised a shilling, to 3s. 6d., then this should prove correct under all ordinary conditions, and include for interest on the outlay incurred in erecting the installation. This price, needless to say, is very low for a good illuminant in isolated country houses. It will even compete with coal gas in villages and small towns, for this seldom costs less than 5s. per thousand feet and often more, and as a rule it leaves much to be desired in its illuminating qualities.

In regard to the attention an acetylene plant needs, and its safety, the average generator admits of everything being done by a gardener, or other quite unskilled person, in from ten to fifteen minutes daily. As a rule a plant is installed of a size that needs daily attention, but if money is spent in having a larger size, then the few minutes attention needed will be bi-weekly or weekly, according to the charge of material (calcium carbide) that the generator will take. There is not the least danger to be feared unless the attendant does one dangerous thing, this being to take a naked light to the generator shed—the gas-making house. There have been accidents, too many, but in every single case it has been the result of gross carelessness, usually attempting to recharge the generator (this having been forgotten in daytime) after dark, using a naked light to do the recharging by. A person may even do this risky thing with impunity with some generators; and in any case if a lamp is stood on the ground about 12 feet away from the generator shed it affords light enough for the simple task that recharging is. Where accidents have occurred lights have been taken into the shed.

The light afforded by acetylene is doubtless the most pleasing known, and not only may plumbers and engineers push this work in safety and with profit, but there is an enormous field for it almost untouched as yet. As a light, and in its general qualities, acetylene has nothing to rival it.

Calcium carbide (CaC_2), from which acetylene is made, is a grey stony substance, formed by fusing together lime and carbon (coke or anthracite coal) in an electric or other high-temperature furnace. The resulting mass, termed an ingot, is then broken into commercial size, and after being picked over is packed for sale.

Acetylene (C_2H_2) is a gas that is evolved immediately calcium carbide comes in contact with water, the reaction being expressed thus:—

Calcium carbide + water changes to lime + acetylene.

$$CaC_2 + H_2O = CaO + C_2H_2$$

From this it will be seen that the chemical association of calcium carbide and water (which occurs immediately they meet) results in the evolution of acetylene, with plain lime (and excess of water) as a waste product. It may be mentioned here that the resulting lime is quite suited for building purposes, lime-washing, and the many uses that can be found for it on a country estate. Theoretically, the lime would be a monoxide or quicklime, but the excess of water makes it finally appear as a hydrate or slaked lime.

The affinity that the carbide has for water is so great that it would serve as a drying agent. It readily absorbs moisture from the air, and if left exposed for a short time it will be found to have become decomposed, yielding its gas to the atmosphere and leaving a heap of lime behind. On this account calcium carbide must always be kept in air-tight receptacles, not only to prevent the waste that would otherwise occur, but also to avoid the production of gas in improper places, where the introduction of a light would cause an explosion. Carbide is always delivered in sealed metal drums, which, when opened, are emptied into the user's own receptacle, which should be provided with some kind of removable compression lid with rubber collar to render it air-tight.

As the generation of acetylene is so easily effected by simply bringing carbide and water together, it might be supposed that the generating apparatus would be of an equally simple character. This in a great measure is true, but for the perfect production and control of the gas certain rules have to be observed,

introducing some detail in the generator. What may be considered as an ideal set of rules is as follows, and, it should be noted, it is quite easy to observe all these in a proper manner when erecting an installation.

1. A generator, whatever its size, should be charged in a few minutes by a person unskilled in mechanics or technical knowledge.

2. Part of the generating plant should consist of an adjustable gasholder, to receive the gas as generated, and deliver it to the house services as required.

3. Every generating plant should be provided with a positive working escape pipe, to allow of excess gas escaping into the open air should the apparatus be carelessly used or excessively overcharged.

4. The gasholder bell should not carry carbide chambers or anything that will cause a varying weight, and consequently a varying pressure of gas in the service pipes.

5. The water of the gasholder must not be used for anything else. Its level should be constant.

6. There should be no operating parts inside the gasholder. All working parts should be exposed to view.

7. Automatic generators should have no "gear." A ball valve and water cock with lever head operated by the holder bell—or something equivalent to this—is sufficient.

8. In every case when the water and carbide come together the proportion of carbide that is wetted should be submerged and remain submerged. The generation of gas is accompanied by heat, which can have a bad effect on the quality of the gas. This rule provides for cool generation, and a gas as clean as crude gas can be.

9. The carbide trays should be divided up (by divisions) so that the carbide is wetted in small quantities at a time.

10. A very desirable arrangement is to have the carbide chambers—the generating chambers—in duplicate, arranged to work alternately, so that one may be opened and recharged while the other is on duty. It will be seen that, otherwise, a single chamber must be exhausted before it can be recharged, and the moment of exhaustion may come at night or at some inconvenient time for recharging.

11. The gas as it comes from the generating chambers, and before entering the holder, should be made to pass through water to wash it. This removes certain impurities and finally cools the gas. This water vessel is known as the "washer."

12. On leaving the holder to enter the house services the gas should pass through a chemical purifier. The purifying material commonly used is bleaching powder in a specially prepared form, and is inexpensive. After this final purification, which is quite necessary, the gas is ready to burn.

13. A desirable adjunct in the house service is a "governor," or automatic pressure regulator.

In Fig. 119 are illustrated the details of a generating plant. This is to illustrate the order of the parts, therefore no particular kind of generator is shown. It is quite usual for the generating chamber and the washer to be attached to the holder, so that all are grouped to go into a small hut or house. The detail, which is marked as provided to discharge condense water, is not always put in, some engineers considering a tee, with the outlet plugged, sufficient to discharge any water that may condense in the pipes. With a properly constructed plant the gas entering the house service carries no more water vapour than coal gas does, but it contains sufficient to make a provision for discharge necessary. In the writer's own apparatus of twenty lights the water collected during a year was not sufficient to show its presence in a troublesome way. It was about a quarter of a gill.

The piping of the house service and its branches is carried out as with coal gas, a rise or fall being given wherever desirable to ensure that whatever condense water may collect shall drain to a convenient point for removal. The sizes of the pipes, however, are considerably smaller, as a much less volume of acetylene is required for a given degree of illumination than coal gas. For the purpose of this detail it may be said that fifteen times as much coal gas is required as acetylene for a light of given candle-power, but it is not practicable to use pipes for the latter of one-fifteenth the size of those used for the former. The following sizes are customarily adopted:—

Number of ½-foot Burners, or Equivalent of other Sizes.	Distance from Generating Apparatus (or from the Main, if it is a Branch Pipe).	Size of Pipe.
	Feet.	Inches.
2	15	$\frac{1}{8}$
5	30	$\frac{1}{4}$
10	40	$\frac{3}{8}$
20	50	$\frac{1}{2}$
50	100	$\frac{3}{4}$
70	130	1
100	150	$1\frac{1}{4}$
150	180	$1\frac{1}{2}$
270	250	2

In carrying out the piping, also in the choice of brackets, it has to be borne in mind, or will be quickly discovered, that acetylene is what is termed a "searching" gas. It will discover and pass through leaky joints and places that would be quite tight to coal gas. Ordinary white and red lead paint may be used for jointing the pipe, but the fitter must not rely too much on the paint. A hot-water or steam fitter makes a sounder job of acetylene piping than the average gas-fitter, but all may do good work if care is used to make soundly screwed joints, with the least possible

quantity of white lead. This searching quality of acetylene often makes trouble with the ordinary quality of iron gas pipe, which appears to have too many faulty places in it when carrying acetylene. This is so noticeable—and expensive in labour—that some engineers always use steam tube for this work. It costs but little more in first outlay, and may save much in the end.

For gas-fittings the choice lies between the best quality fittings of the ordinary kinds, or special fittings which have extra long bodies to the joints and cocks. There is no extra wear, nor chemical action, to produce bad results. It is simply that, with acetylene, a fitting must be used that will be sound at its cock and joints

The burners are of special form, slightly Bunsen in character to rectify the exceeding richness of this gas in carbon. The gas delivery holes are very minute, and, as with most burners giving a flat flame, the gas is delivered as two pin flames which are made to impinge and flatten out. What has been considered the ordinary type of burner resembles Fig. 120. Of all burners it had the greatest use, but it possessed a fault in that the flame could not be turned low without the burner tips "carbonising." This trouble appeared as a small crusted collection of soot, quite spoiling the flame until it had been removed and the burner cleaned. In consequence of this the bracket tap had to be full on or quite closed, if trouble was to be avoided. More recently

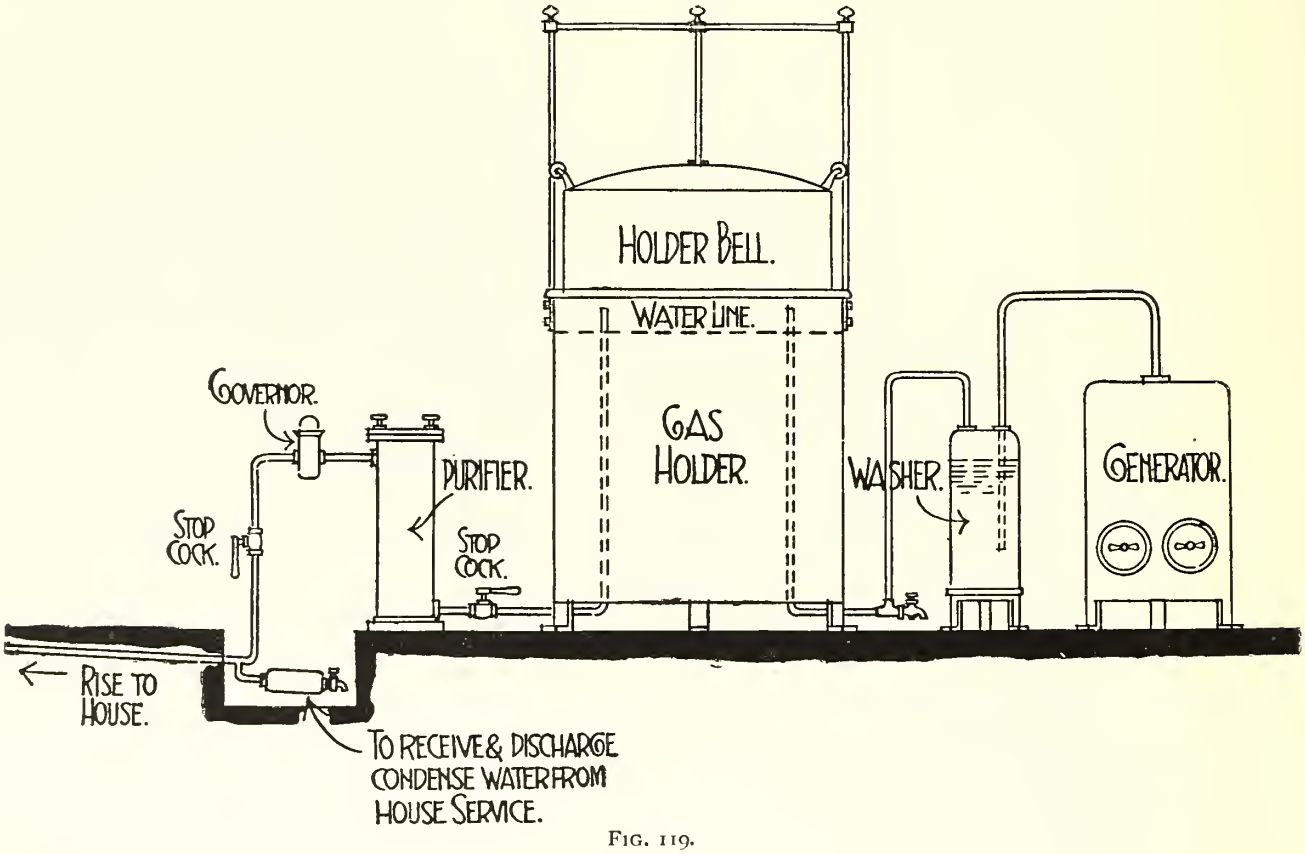


Fig. 119.

and remain sound there when used, otherwise there will be a leak in evidence due to the searching nature of the gas. It is very desirable that copper be avoided in the make of fittings (also in the piping), except for purposes of external ornament. A peculiar chemical action has been found to occur between acetylene and copper, which, although the conclusions arrived at are debatable, is such as to make it desirable that copper be not used where the gas will have contact. Brass, which is an alloy of copper, may be used with freedom and safety. Water-slide chandeliers may not be used, for, as will be learned, the gas pressure with acetylene is too high for water-sealed fittings to be used in the ordinary way.

the firm of Bray & Co. have introduced a burner which is without this fault, and it may be considered that this removed the last difficulty connected with the acetylene industry. Bray's burner is illustrated in Fig. 121. This illustration, it may be noted, shows about twice the actual size of an acetylene flame consuming about ½ foot of gas per hour, giving about a 17 candle-power light.

The light afforded by different sizes of burners is as follows:—

Burner consuming per Hour	With Self-Luminous Flame, gives a Light of
⅓ foot	6.2 candle-power.
½ „	17.5 „
⅚ „	35.0 „

These are sizes ordinarily used, and attention is called to the high illuminating power of the larger burners, which is out of ratio with the gas consumed. It is a fact that the larger the burner the more economical it is, but there has, of course, to be a limit to the size that can be used in residence work. The burners most nearly approaching $\frac{5}{8}$ and $\frac{3}{4}$ foot are best for this

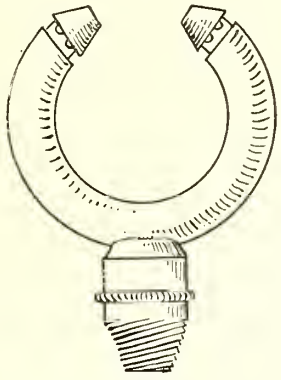


Fig. 120.

purpose, for it is *not* economical to use one large burner in a room that requires two burners (at different points and of suitable smaller size) to distribute the light satisfactorily.

There is another reason for keeping the burners of an installation of about the same size, this being that burners of varying sizes require different pressures of

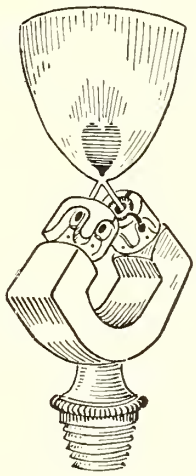


Fig. 121.

gas to afford their best results. The pressures best suited to the burners are as follow:—

Burner consuming Cubic Feet per Hour, or nearest to these Figures.	Most suitable Pressure in Inches of Water.
$\frac{1}{3}$ foot	2 inches
$\frac{1}{2}$,,	$2\frac{1}{2}$,,
$\frac{2}{3}$,,	3 ,,
$\frac{5}{6}$,,	$3\frac{1}{2}$,,
1 ,,	4 ,,

It is seldom that a generating apparatus is so constructed that the holder bell presses down on the contained gas so as to give the exact pressure required at the burners. This is the reason for strongly recommending the use of a governor, as already mentioned, and included in the illustration (Fig. 119).

In setting the governor, or to ascertain the pressure at the burners at any time, a gauge is necessary, and this is illustrated in Fig. 122. It can be home-made if desired, as a piece of $\frac{1}{4}$-inch glass tube can be bent in any gas flame. The figured spaces measure half an inch each, but they register an inch, as it will be seen that the water sinks as much below the zero figure as it rises above it. As illustrated, the water is $2\frac{3}{4}$ inches above zero in one leg and $2\frac{3}{4}$ inches below in the other, and this indicates a pressure of $5\frac{1}{2}$ inches. In other

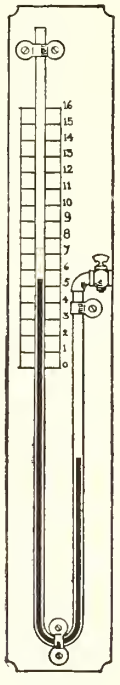


Fig. 122.

words, there is a space $5\frac{1}{2}$ inches in height between the two water levels. By the addition of another cock, to blow into, this gauge can be used for testing a newly finished apparatus. Such an apparatus, before the workmen leave it, should be given a test pressure of 12 to 14 inches of water, and it should bear this with very slight variation for half an hour.

Principles of Generation

The types of generators on the market may be broadly divided into two, the hand-fed or non-automatic and the automatic. The makers of one condemn the other, but, as a matter of fact, both are good. The writer believes the hand-fed principle to be very good, but he always uses the automatic for residence work; but would prefer the hand-fed for, say, village lighting, railway work, barracks, or wherever space and appear-

ance count for nothing, and it is desired to actually see the gas in store, ready for use, each day. The automatic apparatus has (comparatively) a small gasholder, as, being automatic, the holder need only hold say one-fourth the evening's supply at once, remembering that as the store of gas diminishes, more is promptly made without attention.

It is obviously impossible to describe all makes of generators, but two may be taken, one of each kind, to show the principles involved and the detail a generator must have to afford ordinarily good results. Fig. 123 illustrates the Pictet apparatus, hand-fed (non-automatic). The gasholder is of the ordinary kind, as also is the washer, the part needing description being the generating tank. This is an upright closed

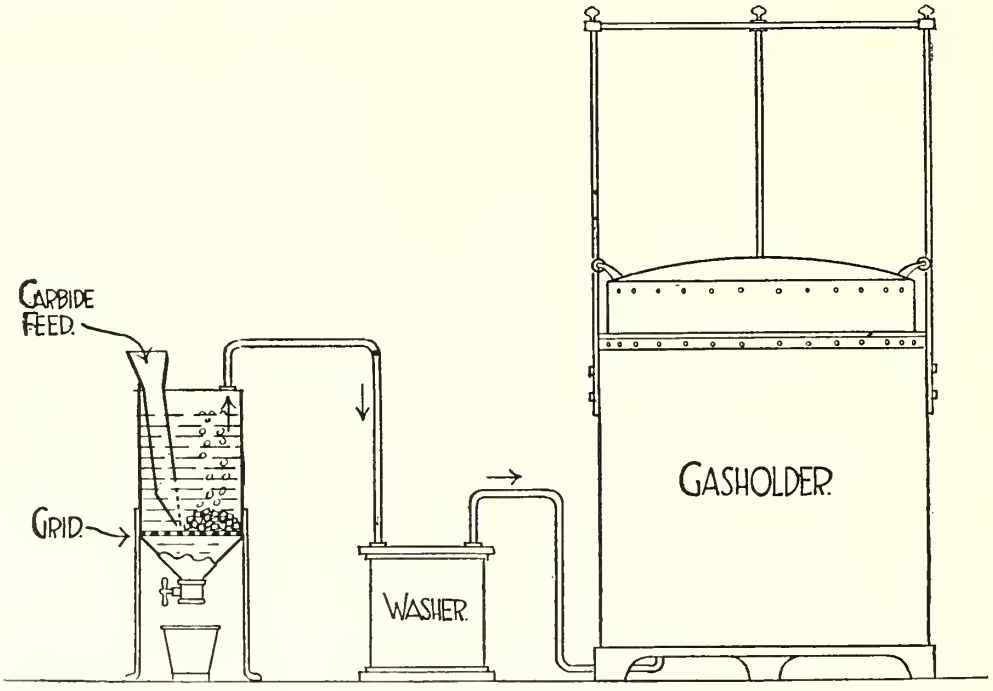


FIG. 123.

tank, conical or taper at the bottom part, the lower end of the cone being fitted with a large full-way cock for the removal of the lime sludge. In the closed top of the tank is inserted a funnel-shaped feeding tube, down which the pieces of carbide are dropped by hand; and the lower end of this tube has its opening at an angle that does not readily admit of gas passing back up it. When the carbide has passed through the tube it falls upon a grid, or grated division, the object of this being to prevent the carbide falling into the sludge which collects in the conical bottom. Sludge (the lime left by the decomposed carbide) does not collect on the grid, as it is practically a cream of lime. When decomposition of the carbide is complete this falls through the grid quite freely. The objection to the carbide falling into the sludge is that this does not admit of water coming with sufficient freedom to the pieces, which, unless of quite small size, generate sufficient heat to form a crust of lime upon themselves. This results in a diminished gas supply, which is, too, of bad quality due to excessive heat during generation. The existence of the grid obviates this by allowing free contact between the water and carbide until all gas is evolved. As previously stated, this type of apparatus has to have a gasholder large enough to receive, at least, a volume of gas sufficient for the longest evening, and the greatest demand of one evening (though so simple an apparatus could be fed after dark without a light). This is a desirable thing in certain instances, but it necessitates a large gasholder which occupies some space, needs a larger hut, and is more expensive than a smaller one. This type of apparatus is said to work on the "carbide-to-water" principle, as distinct from other generators in which the carbide is stationary and the water flows to it.

As an example of an automatic generating apparatus, Fig. 124 may be given. In this the gasholder is of the ordinary kind, but the holder-bell carries a drop-rod from its front edge as shown. A generating chamber and washer come on each side of the holder, supported on brackets attached to the holder tank. The brackets are not shown, nor are the generator and washer on the left side, these being duplicates of those shown on the right. As already stated, it is desirable that the generator parts be in duplicate, to work alternatively, and this provision here exists. Each washer is a plain cylindrical vessel, and it has to be explained that the water in these is replenished and kept at one constant level by a ball valve cistern which is attached to the back of the holder. This cistern is not shown, nor the pipes which connect it to the washers, as they would

complicate the illustration. They can be easily understood to exist.

The action of the generator is as follows:—The carbide tray has its divisions about half filled with carbide, for the mass swells in decomposing. It is then slipped into the generating chamber, the front of which is closed by a compression lid. When the holder bell descends (due to the store of gas being used) the drop rod descends with it, and the arm from this rod presses on the lever which operates the water cock in the supply pipe to the generating chamber. Water at once flows in and wets some of the carbide, resulting in the immediate production of gas, which in turn raises the holder bell and releases the pressure on the lever of the water cock. The cock lever, being weighted at the other end, automatically closes the

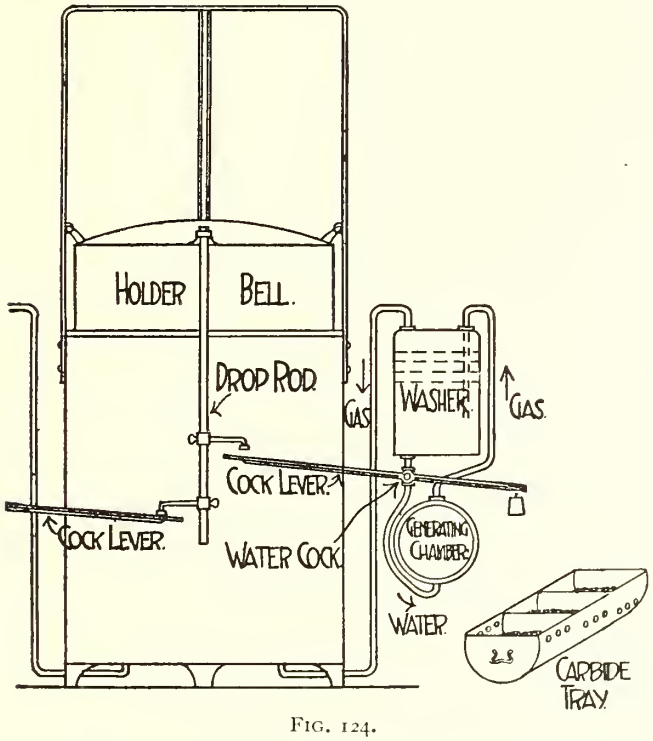


Fig. 124.

cock as soon as the arm rises from the lever. In the illustration the left-hand lever is depressed, causing water to be delivered to the carbide chamber on that side. Should the carbide be exhausted in that chamber the bell, on descending a little lower, will cause the right-hand generating chamber to come into use, and when this is noticed the left-hand one is known to be exhausted and can be recharged. On doing this the position of the arms on the drop rod are reversed (by means of set screws).

It will be seen that the water of the washer is used for generation. The idea of this is to keep changing this water automatically, for otherwise it might get very foul. It will also be seen that the divisions of the carbide tray have holes (for the rising water to enter by) at different levels. This is to ensure that only a small quantity of carbide—one division—be operated on at once.

The Purification of Acetylene

The washer that appears as part of a generating apparatus is a purifying vessel, as it arrests all condensible and soluble impurities,[1] but it does not wholly suffice, as it cannot remove certain gaseous impurities. Phosphuretted hydrogen is the chief of these, and a substance that will arrest this suffices for the final purification. The material most largely used is chloride of lime—bleaching powder; but, although a good material, it caused some trouble at first owing to its being improperly used. It has to be diluted, so to speak, by the addition of some dry inert substance in powdered form, yet porous. Infusorial earth has served the purpose best, but a new and equally inexpensive finished purifying material has been introduced and is having the most favour at this moment. This material is known as "Puratylene," and is a specially prepared mixture of ordinary quicklime and calcium chloride, leaving the finished article like a friable pumice stone. An advantage possessed by this is the simple form the purifying vessel may take; for, instead of arranging the purifying agent (when in powdered form) in muslin bags on trays, or something equivalent to this, the vessel can have a plain interior and be merely filled with the substance named. The gas will pass freely through the mass, yet it cannot get through without intimate contact and satisfactory purification.

Regulations to be observed in erecting an Acetylene Installation

Except for small quantities, calcium carbide cannot be stored without a licence being first obtained. This means that an acetylene generating apparatus, when fixed for use, necessitates a licence being obtained, as the apparatus is useless without a store of carbide; and the quantity of this latter material which may be stored without a licence (namely, 5 lbs. in five 1 lb. tins without any conditions, or 28 lbs. under special conditions) is too little for even a small residence plant. This being realised, it is a good plan to apply for the licence before the apparatus is erected, as the granting of a licence necessitates the attendance of the surveyor to the local authorities, and he will at once say if the location of the proposed store is to his approval. The importance of this arrangement is that the work cannot be condemned afterwards, and as the carbide store and the generator house are one and the same building (in all except very large undertakings) the whole obtain official sanction and approval at once. In building the generator house, space should be allowed for a sufficient store of carbide to prevent the

[1] Notwithstanding the high degree of purity of the ingredients now used in the manufacture of carbide, purification of the resulting gas is necessary.

possibility of running short. It should be arranged that one drum (1 cwt.) should always be in store untouched by the normal demand. The charge for the licence, payable yearly, is 5s. or any less sum. Occasionally 2s. 6d. only is charged. This includes the surveyor's visit.

The carbide store (and generator house) is not allowed to be in or under any dwelling-house or similar building. It lies within the surveyor's power to allow the store to be a lean-to against a house, but it is seldom permitted. It must not be near any forge or fire or source of danger of this kind. It must be built wholly of incombustible material. (Surveyors exercise judgment in this, and commonly allow a wooden house, with brickwork foundation). It must be provided with "adequate means of ventilation." No inflammable materials may be kept in this store. The store must be kept locked at all times when not being actually used.

Remembering the carelessness of outdoor servants, farm hands, and others who usually attend to the generator, it is wise to adopt every possible precaution against explosion. A bold notice should be painted on the door to warn everyone that naked lights must on no account be taken into or near the store; nor may smoking be allowed there, *as acetylene can be ignited by glowing tobacco—pipe, cigar, or cigarette.*

CHAPTER XIII

A COMPARISON BETWEEN GAS AND ELECTRIC LIGHTING

(Contributed by H. V. Margary)

The particular means of illumination to be employed in any given building is an important point constantly arising. As a rule both gas and electricity are available, and each have advantages not possessed by the other. In some cases it would be inadvisable to use gas, in others electricity would be deemed out of place, while a combination of both is occasionally preferable to either alone.

Considering only, for the moment, the conditions where a public supply of both illuminants is available, the following points of view arise:—

1. Cost of Installation. 2. Cost of Supply. 3. Suitability. 4. Fire Risk. 5. Health.

1. Cost of Installation.—Keen competition has reduced the cost of an electric-light installation to a point very much in favour of the user, while the cost of gas installations has not greatly declined. This point goes rather to the advantage of electricity. The cost of wiring a 12-roomed house, say, for ordinary effects, and including fittings of simple character, would be approximately £25. Installing gas under similar conditions would cost £30. In like manner the relative costs would favour electricity for installations of any size, though with larger installations the difference would be less, as the cost for increased sizes of cable rises much more than that of larger sizes of gas barrel.

These figures are based on competition lines, but include installations which would meet the conditions and requirements of the various authorities concerned.

More elaborate methods of wiring would raise the cost of laying in the wires, but in the matter of fittings electricity would always be cheaper.

Prime cost, then, is not a very important point, and comparison would vary in effect according to the design of the building. For instance, it is demanded of electricity that each lamp or group of lamps shall be controlled from one or more central points, often some distance from the lamps they govern. Where there are long runs to the burner, gas would be the cheaper to install, simply because the user is content to turn on at or close to the burner.

2. Cost of Supply.—Where cost is a matter for consideration, as is generally the case with ordinary dwelling-houses, the favour would be shown to gas. Were there no other disadvantages to be considered under this head, the electricity bill would be generally double that of the gas bill, although the opportunities for economy are much greater with the self-lighting illuminant and its easily handled switch.

This comparison is based upon gas at 2s. 8d. per 1000 feet, and electricity at 5d. per unit; the difference will of course vary with the local charges, becoming nil at one point and reversing in favour of electricity where gas is 2s. 6d. and the electricity is 2d. So far the advantage lies with gas as regards cost per annum, but the important point of the preservation of the interior decoration somewhat reduces this. Where electricity is employed, ceilings, which would otherwise require to be distempered every spring, will last for three or four years, and in like proportion paint work, pictures, and ornaments generally are saved from the ill effects of the acid fumes resulting from the combustion of coal gas.

The foregoing statement assumes that the smoke and fumes from the fire are efficiently carried away, and it should also be borne in mind that the difference is perhaps more apparent in the provinces than in London, where fogs and impure atmosphere have a considerable effect.

To sum up, the question of relative costs of supply is modified by redecoration. Gas will probably be cheaper in the ordinary dwelling-house, while electricity should be used where decorations are on elaborate and expensive lines; but in any case it must be remembered that the cost per annum for redecoration is at least three times as much where gas is used.

In the matter of upkeep, electricity compares favourably with incandescent gas; but would be more expensive compared with gas consumed by means of the ordinary jet.

Although the electric incandescent lamp gives off a fair amount of heat, a space lit by gas would be comparatively warmer. Advantage is taken of this difference wherever heat is essential, as in tobacconists' premises. On the other hand, the moist acid fumes from the gas-burner are, in such premises as those of gold and silversmiths, distinctly deleterious. In such cases the cost of supply is not so important.

3. Suitability.—There is little doubt that in point of "suitability" electricity has the advantage of gas, with a few exceptions briefly referred to in the last

paragraph. Modern progress in the design of electric-light fittings and lamps enables any desirable effect to be easily obtainable. The soft warm light emanating from a gasalier containing a cluster of comparatively small gas jets and softened by opal or tinted globes is obtained at once by the simple artifice of frosting or tinting the glass of the electric-light bulb, while in design the artist has a much freer hand in developing an idea through the medium of an electrolier. It is scarcely possible to design an electric fitting which an electrician cannot supply with power, while the gasalier demands pipes and taps which, however cunning and skilful the designer, are bound to cramp his art to a considerable degree. Effective Louis Quinze candle fittings, for instance, which are practically impossible where gas is the only supply, are quite an easy matter for the electrician, and form a most admirable adjunct to the principal lighting of drawing-rooms, studies, or boudoirs; in fact, it is a question whether any central electrolier or pendant is really admissible in a modern drawing-room of ordinary size, now that there are so many exquisite wall fittings and shaded standards both for the floor and table.

Beautiful effects of modulated light simply become a matter of taste, unconfined by any limits when electricity is employed. There is no necessity to light the whole room with equal intensity to ensure sufficient light everywhere. On the contrary, this must be at the expense of certain items in the decorative scheme which might be better lit by "suggestion" than actually—that is to say, in any room furnished as much for beauty as utility, each distinctive point or piece in the scheme must be treated as its character demands. A piece of bold carving in dark material and of heavy design should, if possible, be illuminated from two or three places at the back or inside with lamps of low candle-power, and where the lamps themselves cannot be entirely hidden they should be enveloped in a glass flower or vase of suitable tint, or be suspended in some quaint eastern lantern in keeping or contrast with the design. It is possible by this means to greatly enhance the artistic value of such a piece of furniture, a thing which cannot be done where gas is employed. Speaking generally, gas will produce bright lights and dense shadows, while electricity—a pliant servant in the hands of the artist—can be applied to produce any desired effect.

The principal lighting of any ordinary dwelling-house or mansion could be more effectively and simply carried out by electricity than by gas, while the former is also much more useful for temporary additional lighting.

4. Fire Risk.—A properly carried out electric-light installation is considered by the fire offices to be safer than any other, but a badly wired building is much more dangerous from a fire point of view than one installed with leaky gas pipes. Of course, in the event of leakage only, gas is poisonous when compared with electricity. On the other hand, electricity practically always gives rise to heat at the point of leakage, and in this respect is more dangerous than gas. On the other hand, in case of leakage there is no controlling apparatus to automatically turn off the supply in case of gas, but the fuse, in a properly carried-out electric-light installation, will melt when a dangerous leakage of current takes place.

Fire due to contact with a burner is impossible with electricity, which is not the case with gas; while fires have been caused at the time of lighting the gas by the match or taper used for that purpose.

5. Health.—It is somewhat a matter of opinion as to whether either illuminant has any deleterious effect, provided there be an ample supply of oxygen for the gas as well as for human consumption, together with an outlet for the products of combustion, such as carbon dioxide, traces of sulphur oxides, and moisture. Of these products carbon dioxide cannot be said to be healthy, although it is claimed that some of the sulphur oxides are health giving; but moisture is certainly not healthy. However, the worst of these products, carbon dioxide, is a heavy gas, and will therefore take its position about the floor, provided good ventilation does not remove it in its heated state. The most serious point to consider, therefore, is the consumption of oxygen, so that, provided there is good ventilation, gas could not be considered particularly unhealthy. On the score of health, nothing can be said against the electric incandescent lamp, and the only exception to a clean bill for electricity in general is to be found in the special form of electric arc lamp called the "Flame lamp," in which coloured effects are obtained by impregnating the carbons with highly poisonous chemicals. These lamps should never be used for interior lighting.

The foregoing comparisons have been based upon the assumption that a public supply of either illuminant is available. It is therefore now necessary to briefly discuss the position of an isolated country house, institution, or factory which is presumed to be of a size not permitting the use of oil or tallow. Isolated gas plants are now rarely, if at all, used, for there are many disadvantages. In first cost the gas plant is more expensive than the electric light plant, as a considerable number of processes have to be gone through in order to produce gas from coal, while electricity is obtained by comparatively simple means. Owing to the small demand, there is a difficulty in the supply of the necessary skilled labour for the gas plant, and much more intimate knowledge of gas production is required than knowledge of electricity to run an electric-light plant. Proximity to a railway siding is more essential to the gas plant than to the electric plant, as a much greater amount of power may be obtained from liquid than solid fuel, though this point becomes equally divided when electricity is produced from a "power-gas" plant. It is necessary here to mention that power-gas plants do not require the skilled attention of illuminating gas producers, while their product is not fit for light.

As it is now possible to generate electricity at 1d. per unit, and with reasonable continuity, the electric-light plant should be given preference.

After carefully considering the advantages and disadvantages from the five most important points of view, it will be seen that electricity forms the best means for illumination, while for ordinary lighting gas is the cheaper.

Having considered the subject somewhat from the standpoint of the dwelling-house, it would be well to look into the position of the business premises, the theatre, and the public institution.

The business man will go deep into the cost per annum, and against this he will place the value of the character of the light from the advertisement point of view, and the ease and safety with which light is turned on and time saved in the operation. If he use gas his premises will need less heat but more ventilation. If, however, he has the space required for this purpose, and is prepared for the initial outlay, he will install the electric-light plant, provided that the amount of light he wants warrants this.

A theatre is obliged to use electricity, if only for stage effects. There are many almost inaccessible points where the electric lamp might almost be considered essential. Electricity gives light with minimum heat, and requires no oxygen from the air, while at the footlights it is much safer than gas. Lights may, too, be extinguished during the play instead of being turned down, as must gas, thus making for economy. In the theatre, of all places, it is essential to keep the decorations bright and clean. Gas must still be used as stand-by, but with this exception everything indicates electricity for the theatre.

Town halls and assembly rooms will follow the lead of the theatres, suitability, safety, and convenience weighing more than cost, while barracks, hospitals, and similar buildings could be lit by the cheaper light.

CHAPTER XIV

SIMPLE MAGNETIC AND ELECTRIC PHENOMENA

(*Contributed by H. V. Margary*)

It is advisable that a man who wires a building for electric-lighting purposes should have a very fair knowledge of the properties of the forces called magnetism and electricity. The more extensive the wireman's knowledge of these properties is, the more likely is his work to be thoroughly sound. Many men, however, wire buildings with a very limited knowledge of the theoretical requirements of such work, being guided by simple rules of thumb, their own experience, and the knowledge and experience of those from whom they learnt their trade. It is here purposed to treat wiring from the theoretical as well as from the practical point of view, and for the purpose of facilitating description in the subsequent chapters a few of the simple properties of magnetism and electricity are given.

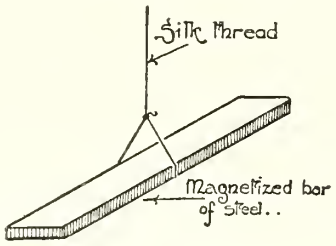


Fig. 125

Simple Magnetic Phenomena

To the more practical-minded reader some of the simple phenomena set forth in this chapter may appear foreign to the practical requirements of electric wiring. It must be remembered, however, that the majority of our readers may have practically no knowledge of the properties of electricity whatever or an opportunity of "picking up" such knowledge. The architect, for instance, is rarely possessed of a knowledge of electricity, yet he must from time to time write Specifications to govern the wiring of his buildings, and lacking experience he can only fall back on theory. It is also necessary to mention the various units used in electrical measurements, so that a knowledge of a few elementary facts concerning electricity must be gained before these can be explained.

The peculiar force known as magnetism was first discovered by mankind to be possessed by a mineral form of iron oxide known as magnetite, or more popularly as lodestone. This material possesses the property of attracting small particles of iron, and if a piece of steel is rubbed with a piece of lodestone the magnetic properties of the lodestone are imparted to the metal. If a symmetrical bar of steel be stroked in one direction with a piece of lodestone, and suspended from a fine silk thread, as shown in Fig. 125, and allowed to oscillate, it will be found that it always comes to rest in a direction approximately north and south, for which reason the end of the magnetised bar of steel which, when suspended, turns towards the north is called the

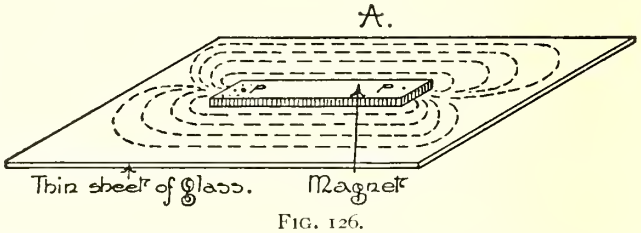


Fig. 126.

north or north-seeking end. The other end is called the south or south-seeking end.

If another piece of steel be magnetised and then suspended near the first magnet, it will be found that the north-seeking end of the former will be attracted by the south-seeking end of the latter, while it will repel the north-seeking end. This last fact is sometimes expressed as follows:—*Like ends repel, unlike ends attract one another.*

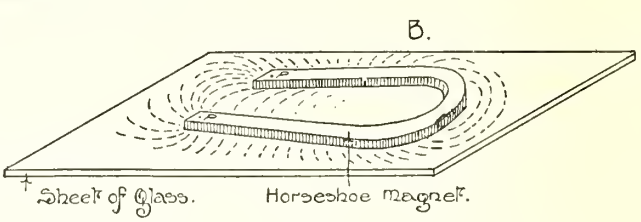


Fig. 127.

If a magnet formed as described above be placed on a table beneath a sheet of glass, as shown in Fig. 126, and upon the glass fine iron filings be sprinkled, it will be found that these filings arrange themselves in definite lines curving from one end of the magnet to the other. These lines represent the lines of force created by the magnet in the particular plane of the sheet of glass. It can be shown that similar lines exist in every plane passing through the axis of the magnet.

It should be noticed that these lines of force appear to emanate principally from two points P, P, near the ends of the magnet. These points are called *poles*, the north-seeking end being called the *north pole* and the south-seeking end the *south pole*.

The lines of force due to a magnet of the horseshoe form are shown in Fig. 127. The lines of force are regarded as emanating from the north ends of magnets. The space around a magnet in which the lines of force exist is called *a magnetic field*.

Simple Electric Phenomena

If a plate of zinc and a plate of copper be immersed in a vessel containing dilute sulphuric acid (see Fig. 128), and if the plates are connected above the acid by a piece

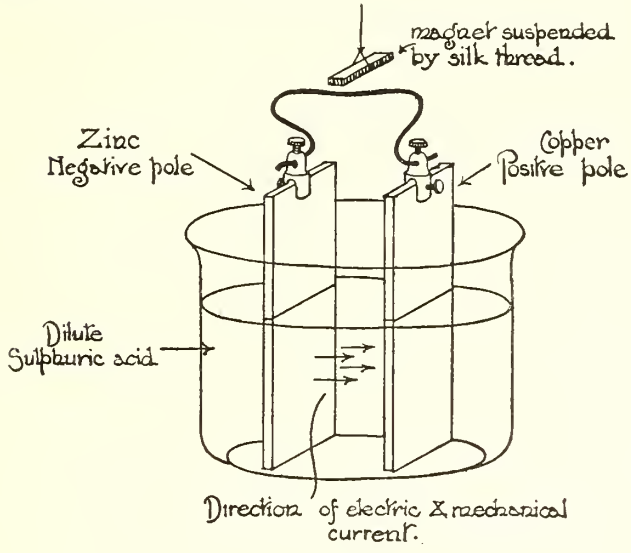


Fig. 128.

of wire, a circulation of the liquid will be observed from the zinc to the copper plate, while bubbles of gas will collect upon the copper plate. If now a light piece of magnetised steel, suspended from a fine silk thread, be placed near the wire which connects the two plates, it will be seen to set itself in some definite position relatively to the wire, indicating that the wire has become possessed of a magnetic power. This is indeed the case, for apart from the mechanical and chemical action which has been observed, a physical action also occurs, namely, a current of electricity passes through the wire. If the wire be wound into a spiral, as in Fig. 129, it will be found that on the passage of a current of electricity a magnetic effect is produced in the neighbourhood of the wire similar to that produced by the magnet in Fig. 126.

A piece of soft iron placed in the axis of the spiral of wire has the effect of increasing its magnetic properties. The magnetic effect of a spiral is also increased with the number of turns of wire, the increase being in direct proportion to the number of turns.

If the ends of a coil of wire are connected to the terminals of a galvanometer (*i.e.* an instrument for indicating the flow of a current of electricity), and a magnet be suddenly placed in the centre of the coil, the needle of the galvanometer will give a swing in one direction, indicating that a current of electricity has been created in the coil by the movement of the magnet. If the magnet be suddenly withdrawn from the coil the indicating needle of the galvanometer will swing in the opposite direction, indicating that a current of electricity has been produced flowing through the coil in the opposite direction to the current produced by inserting the magnet in the coil. It will be observed that the more rapidly the magnet is inserted or withdrawn from the coil the more pronounced is the movement of the galvanometer needle, and therefore the greater is the current causing this move-

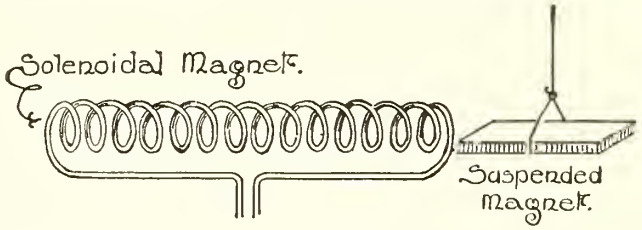


Fig. 129.

ment. So long as the magnet is at rest, or, in other words, so long as the coil is not cutting the lines of force of the magnet, no current flows through the coil, but so long as the magnet moves within the coil a current is created. A current may also be created by keeping the magnet stationary, and moving the coil anywhere within the magnetic field in such a manner that lines are cut by the turns of wire. A current produced within a circuit without actual contact with another circuit to which a current is flowing, or by a magnet as just described, is called an induced current, and it is upon this principle of induced currents that innumerable practical appliances such as the dynamo and the transformer depend.

The Principles of the Dynamo

If a coil of wire, such as C, Fig. 130, be revolved between the poles of a horseshoe magnet, a current will be induced in the coil. To utilise this current some means of conducting it away must be devised. An early device for this purpose consists of a tube of metal split into two pieces, as R and T mounted upon the same axle as the coil C. The fixing of R and T to the axle must be made with some substance which will not conduct an electric current. Two springs or *brushes* of metal, A and B, are mounted to press upon R and T at diametrically opposite points, and in a particular position relative to the poles of the magnet, and the external circuit is connected to these springs.

It will be seen that, as the coil C revolves, the current passing through it is reversed twice in every revolution, but the direction of the current in the external circuit is always the same, for, when the current is flowing in

the direction indicated by the arrows in the coil C, the half of the split tube R is in contact with A, and when the current flows through the coil in the opposite direction the other portion of the split tube is in contact with A; so that the current in the external circuit is

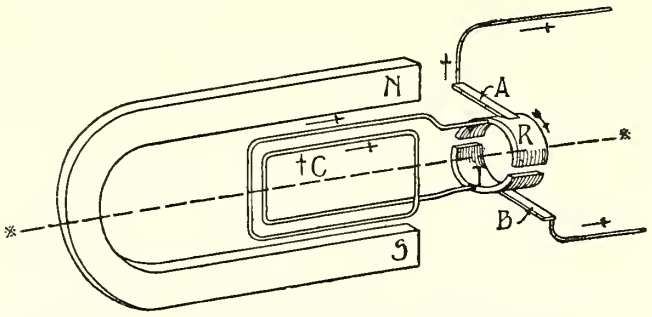


DIAGRAM OF CONTINUOUS CURRENT DYNAMO.

FIG. 130.

uni-directional. A current so produced is called a *Continuous* or *Direct* current.

Dynamos are sometimes constructed on the principle shown in Fig. 131, with two complete rings of copper upon which the brushes press, and with such an arrangement it will be seen that the current in the external circuit changes its direction of flow twice in every revolution of the coil. Such a dynamo produces *alternating current*, and is usually called an *Alternator*. The axle of a dynamo with the coils and split tube mounted upon it is commonly called the *Armature*, and

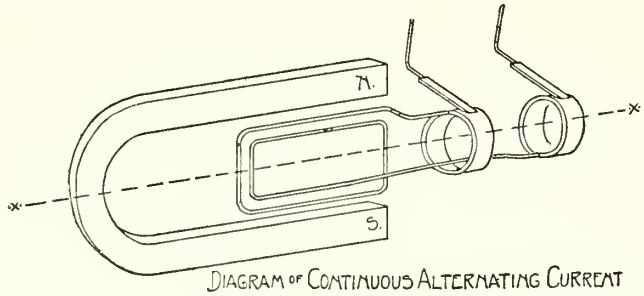


DIAGRAM OF CONTINUOUS ALTERNATING CURRENT DYNAMO.

FIG. 131.

the magnet is called the *Field magnet*, because it creates the magnetic field in which the coils are revolved. Sometimes the field magnets of an alternator are revolved, while the armature remains stationary.

It should also be observed that, as the coil revolves between the poles of the magnet, the number of lines of force cut by the coil will vary with every position of the coil. Thus as the coil passes through the position shown in Fig. 130 a maximum number of lines of force for any constant speed of the coil will be cut; and as the plane of the coil becomes more horizontal, so the number of lines of force cut thereby is decreased. It has already been said that the current induced in a coil varies in the direct proportion to the number of lines cut, and it follows, therefore, that the current will not be steady if only one coil is used. To avoid this defect a dynamo is made with a great number of coils spinning between the magnets, the ends of which are connected to a number of pairs of hard copper strips in place of the two halves of the split tube R and T. Such an arrangement of copper strips is called a *Commutator*.

In practice it is found that electromagnets—*i.e.* magnets produced by passing a current round a coil of wire having an iron core—are more suitable for field magnets than are large permanent horseshoe magnets. The iron used for the core is of such a nature that it retains a certain small amount of magnetism, so that a small amount of current may be generated in the armature coils, which is passed round the field

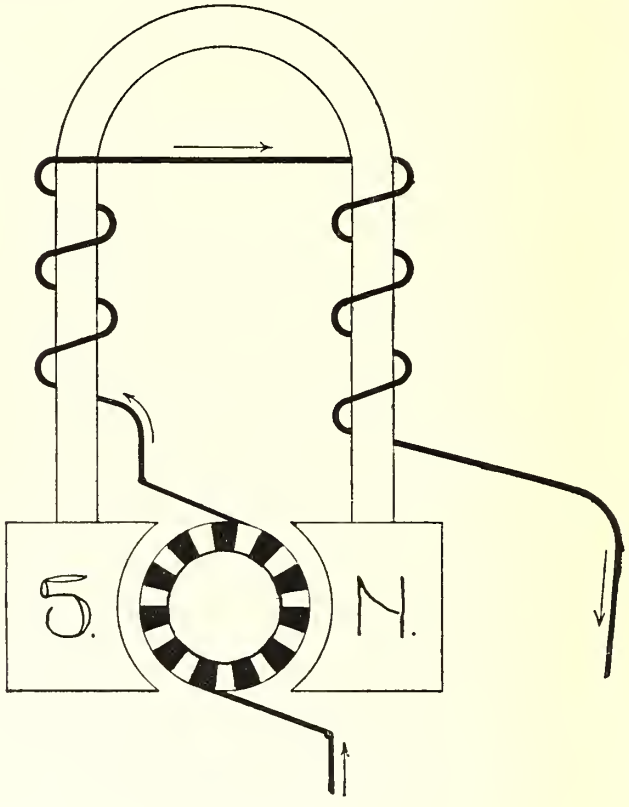


FIG. 132.

magnet coils. This current strengthens the field magnets, and the current in the armature coils increases accordingly. By this process the maximum strength of the field magnet is reached.

The methods of winding the field magnets of a dynamo give rise to the following classification:—Series-wound dynamos, Shunt-wound dynamos, and Compound-wound dynamos.

Series-wound dynamos.—In these the winding is so arranged that the whole of the current generated in the armature coils passes round the field magnets before it reaches the external circuit, as shown diagrammatically in Fig. 132. This type of dynamo is very little used in practice, except for lighting arc lamps

in series, and it is quite unsuitable for changing accumulators or for any purpose where the resistance of the external circuit is not constant, and the dynamo should be designed to work with a particular external resistance.

Shunt-wound dynamos.—In this type of machine two paths are provided for the current, one from one brush A, as shown in Fig. 133 (the whole connection is not shown), through the external circuit to the other brush B, and the other from brush A round the field magnets to the other brush B. When a circuit is divided into two or more paths the amount of current passing in each path is inversely proportional to the resistance of the paths. In a shunt-wound dynamo only a small proportion, usually from two to three per cent. of the total current, passes round the field magnets, and therefore the windings must be composed of much smaller wire of a high resistance compared with the external circuit and winding of the armature than is necessary in a series-wound dynamo.

Compound-wound dynamos.—It is usual to run dynamos at a constant speed, and it would be very awkward if the dynamo varied its pressure according to the number of lights which are switched on and off from time to time. It is therefore necessary, where this inconvenience is to be avoided, to wind a dynamo with series as well as shunt windings, so that should the resistance of the external circuit vary, the pressure remains constant. This is called the compound method of winding. It will be clear from the diagram (Fig. 134) that, as the resistance of the external circuit decreases, the series windings strengthen the field magnet, and the proportion of series and shunt windings should be such that a constant pressure is maintained.

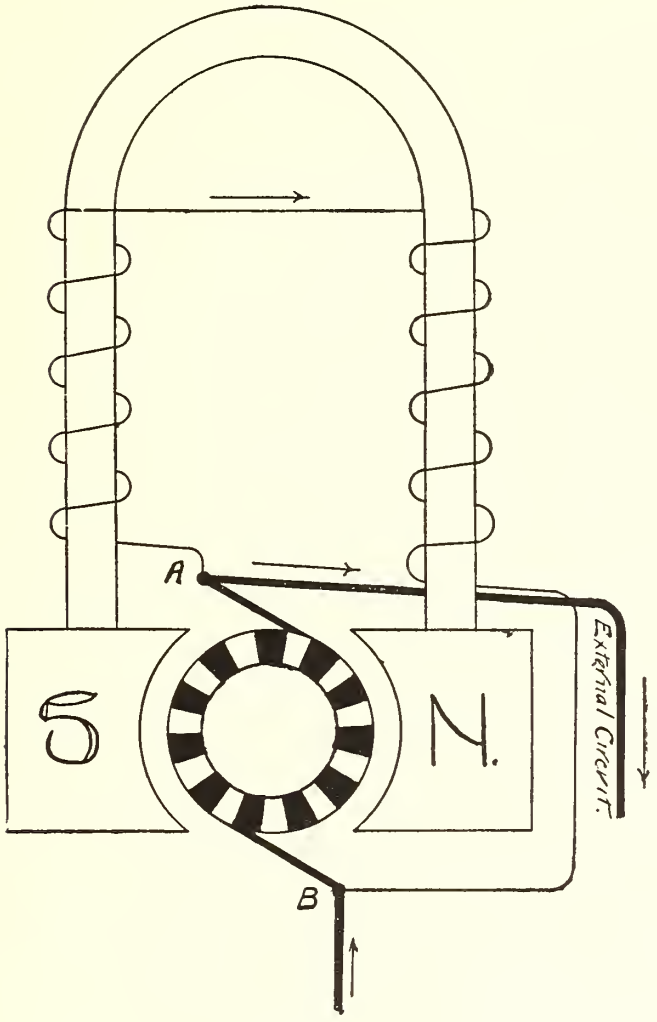


Fig. 133.

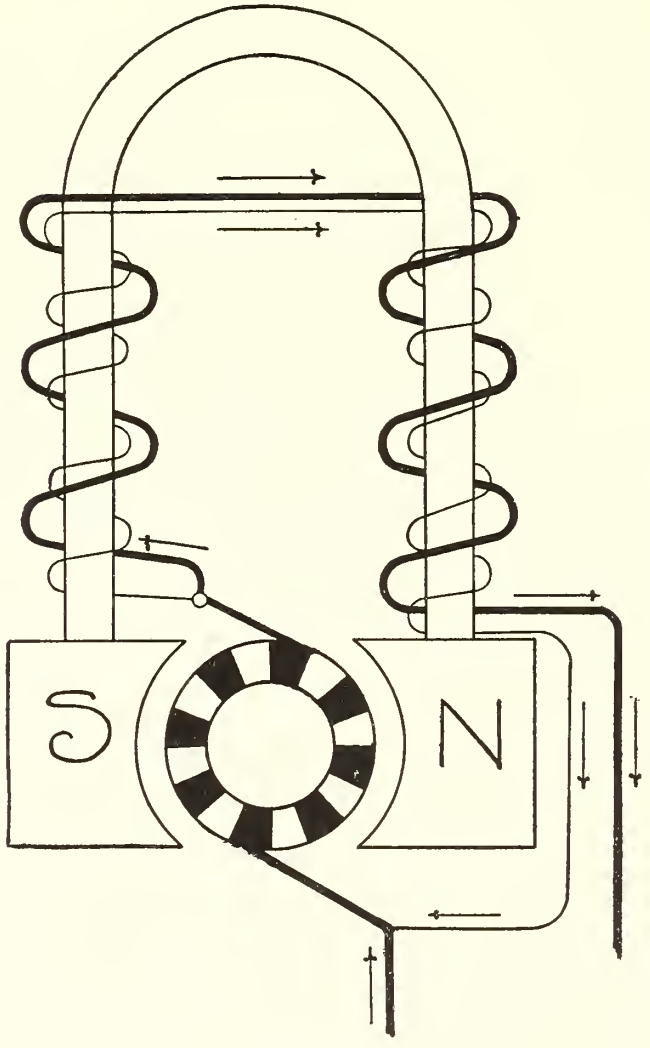


Fig. 134.

CHAPTER XV

UNITS USED IN ELECTRICAL MEASUREMENTS

(*Contributed by H. V. Margary*)

It is essential to become familiar with the units used in electrical measurement before the principles of wiring a building for lighting purposes can possibly be understood. The units used in electrical practice are based upon the fundamental units of length, mass, and time, and the C.G.S. (Centimetre, Gramme, Second) system of units is always employed.

A more vivid idea of the electrical units may be obtained by first gaining some knowledge of the following mechanical terms :—

Force is that which alters or tends to alter the state of rest or of uniform motion of a body.

The C.G.S. unit of force is the force which imparts a velocity of one centimetre per second to a mass of one gramme in one second. This unit is called a *Dyne*.

Work. An agent is said to do work when it causes the point of application of the force which it exerts to move through a certain distance.

A C.G.S. unit of *work* is done when a force of one dyne has been exerted through a distance of one centimetre. This unit is called an *Erg*.

Energy is the capacity of any agent for doing work. Thus a moving mass by virtue of its motion, or a compressed spring by virtue of the stress between its compressed particles, are each capable of doing work. The unit of energy is likewise the *Erg*.

Power is the rate at which work is done. This is expressed in ergs per second.

Unit of Magnetic Force

It has been explained how the pole of a magnet either of the bar or solenoidal form will exert a repellent or attractive force upon the pole of another magnet according as the poles concerned are like or unlike. Advantage is taken of this fact for the measurement of magnetic forces. Thus a pole is said to be a *unit pole*, or to possess a unit of magnetic force, when it exerts a force of one dyne upon a similar pole placed at a distance of one centimetre from it.

Unit of Electric Current.—This may be measured by its magnetic effect upon a unit pole under specified conditions ; thus if a current passing along a conductor, one centimetre in length and bent into an arc of a circle of one centimetre radius, exerts a force of one dyne upon a unit pole placed at the centre, the current is said to be one absolute unit of current.

Ampère.—The absolute unit current is considered to be too large for practical purposes, and in consequence the practical unit has been taken as $\frac{1}{10}$ of the absolute unit. This is called the *Ampère*. The ampère is represented practically by the current which, when passed through a solution of nitrate of silver, in accordance with a definite specification, deposits silver at the rate of 0.00118 gramme per second. The ampère does not give an idea of the quantity of electricity passing through a conductor, but serves more as a gauge to indicate the size or volume, so to speak, of a current. The quantity of electricity is given by multiplying the current by the time during which it flows, and an unit quantity of electricity is said to pass any point in a conductor when one ampère flows for one second. This unit of quantity, which is called a *Coulomb*, is rarely made use of in practice, but serves by inference to indicate the value of an ampère. An analogy may be drawn between the flowing of water through pipes and the passage of current through a conductor. In the former case the water has a certain definite volume per unit length of pipe ; but no idea of the quantity of water delivered by the pipe is obtained until the number of such volumes which have flowed through the pipe in a definite time is known. So with a current flowing in a conductor, no idea of the quantity of electricity can be formed until the time during which it flows is taken into consideration.

Electromotive Force

This term is used to denote the force which moves or tends to move electricity from one point in a conductor to another. The analogy of the water pipes will again be useful in explaining the nature of electromotive force, or E.M.F., as it is usually abbreviated. The rate of flow of water in pipes depends not only upon the pressure or head of water, but upon the resistance offered by the pipes. Thus if the pipes are choked with dirt, they will not deliver the same amount of water as when the pipes are clear, although the head of water is the same in each case. So with electricity in a conductor, the quantity that passes any point depends upon the electromotive force and the *resistance* of the conductor. Just as water flows from a cistern at a high level to a tap at a low level, so electricity may be regarded as flowing from the positive pole of a

battery or dynamo towards the negative pole, the flow being maintained by the difference of pressure, or the *difference of potential* as it is called, between the two poles.

Unit Electromotive Force, or unit difference of potential, exists between two points of a conductor when an expenditure of one erg is required to force one unit of positive electricity from one point to the other against the electric force. This is the absolute unit of electromotive force.

Unit of Resistance.—A conductor is said to have one absolute unit of resistance when it requires unit difference of potential to cause unit current to flow through it.

Ohm.—The practical unit of resistance is the ohm, which is 10^9 of the absolute unit of resistance, and is represented practically by the resistance of a column of mercury 106.3 centimetres long, and 14.4521 grammes in mass, at 0° C. A unit of 1000 ohms is called a *megohm*.

Volt.—The practical unit of electromotive force is called the volt, and is that electromotive force which, applied to a resistance of one ohm, will cause a current of one ampère to flow.

Ohm's Law states that the current flowing between two points of a conductor is directly proportional to the electromotive force and inversely proportional to the resistance. This, expressed algebraically, is

$$C = \frac{E}{R}$$

$$\text{or,} \quad E = C\,R$$

$$\text{or,} \quad R = \frac{E}{C}$$

where C = current in ampères; E = electromotive force in volts, and R = resistance of conductor in ohms. One thousand ohms is called a megohm. These formulæ are necessary for most practical calculations.

Electrical Power.—The term power as applied to electricity represents the rate at which electrical energy is produced or consumed.

Watt.—The practical unit of electrical power is the *watt*, which is the power produced by a current of one ampère flowing at a pressure of one volt. It should be noted that a watt is equivalent to ten times the absolute unit of mechanical power, namely, ten ergs per second. The value of the watt may be expressed as follows:—

$$1 \text{ ampère} \times 1 \text{ volt} = 1 \text{ watt}$$

$$\text{or,} \quad C \times V = W$$

This formula is of great value in practical calculations. A unit called the *kilowatt*, consisting of 1000 watts, is often used for convenience in practice, as, for instance, to indicate the rate at which a dynamo can produce electrical energy, or the rate at which energy is consumed.

Watt-Hour.—To indicate the actual amount of work done in a given time, the unit known as the *watt-hour* is employed. For convenience sake, a unit consisting of 1000 watt-hours is used in practice, and is known as a Board of Trade Unit. It is this unit which is referred to upon a householder's electric light or power bill as so many "units" at such and such a price each.

CHAPTER XVI

WIRES AND CABLES—JOINTING

(*Contributed by H. Y. Margary*)

The term cable strictly applies to a conductor composed of a number of strands of wire. Cables are often spoken of as wires, conductors, or leads. The term wire, however, more strictly applies to a conductor composed of one strand only. The cables used for wiring a building for electric light are composed of drawn copper wires covered with some insulating material. When single wires are used they should not be smaller than No. 18 S.W.G. (Standard Wire Gauge) or greater than No. 16. The reason for limiting the size of single wires is that if too small they are liable to break, and if too large they are so inflexible that they cannot be easily drawn into casing or conduits, or adapted to awkward corners, without causing mechanical injury to the insulation. The smallest stranded cable in general use is composed of 3 strands of No. 22 S.W.G. A cable composed of 3 strands of No. 22 is written thus—3/22, a cable composed of 19 strands of No. 20 is written 19/20, and so on. The sizes of cable in general use are given in the first column of the table on page 180.

Conductivity of Cables.—The copper used for the cables should be of at least 98 per cent. conductivity; that is to say, its conductivity should be at least 98 per cent. of the conductivity of chemically pure copper.

Insulation of Cables.—The copper of which the conductors are composed is covered with a coating of non-conducting material, or dielectric as it is called, to prevent the cables from touching and the current from escaping to earth. There are numerous materials used for insulating cables, such as indiarubber, guttapercha, paper, bitumenised fibre, etc. There are generally two descriptions of cable used for house wiring,—those insulated with a material as a dielectric, which is itself so impervious to moisture that it only needs further protection from mechanical injury and from vermin; and those insulated with a material as dielectric, which, in order to preserve its insulation qualities, must be kept perfectly dry. Rubber and gutta-percha are used in the former description of cable, in which case the dielectric is drawn immediately over the copper and protected from abrasion by a protective binding of cotton, silk, braid, or tape. Paper is used in the latter description of cable, and it is usually protected by an envelope of lead drawn closely over the dielectric, or else encased in thoroughly waterproof tubes.

Insulation Resistance

Although the insulating material is spoken of as a non-conductor, it will not absolutely prevent the passage of current but allows an infinitesimal amount to pass, the actual amount varying with the thickness and quality of the dielectric. It is usual, therefore, to specify the insulation resistance to be not less than 600 megohms per statute mile. The minimum allowable thickness of dielectric for various sized cables is given in Column 6 of the table on page 180.

Several simple tests may be made to determine the quality of the rubber insulation on cables. Cut off about a foot of the cable to be tested, carefully remove the silk or braid and draw out the wires. Stretch the rubber to double its original length and clamp it in this stretched condition for 24 hours. When it is released it should not be more than 15 per cent. longer than the original length. Another good test is to carefully weigh a piece of insulation rubber stripped from a cable, then burn it and weigh the resulting ash. If the rubber is of good quality the weight of the ash should not be more than 40 per cent. of the weight of the original piece of rubber.

Jointing Cables

It is of the utmost importance that when cables have to be joined the joints should be most carefully made by skilled workmen. Bad joints may not become apparent at first, but sooner or later they are sure to do so, when the defect can often only be remedied by the destruction of elaborate decorations, such as frescoes or panelling.

Even in good work, when an installation proves faulty, the engineer always looks to the joints, and more frequently than not he discovers the fault by so doing.

Moreover, bad joints do not usually show themselves when tests are carried out upon the conductors, and it is always a wise plan, therefore, to have all the jointing work under the supervision of a thoroughly reliable man.

The method of jointing two lengths depends chiefly upon the size and construction of the cable.

To joint *small wires* of a single strand, the two ends are stripped of the protecting and insulating material to a length of about 2 inches each. The

copper is thoroughly cleaned by scraping or rubbing with fine emery cloth, and the two ends are twisted together and soldered into a solid mass. The joint is then insulated by binding the stripped wire with two layers of pure rubber strip, and finally protected by a layer of prepared tape stuck on by means of rubber solution.

To joint a stranded cable of only 3 strands, the

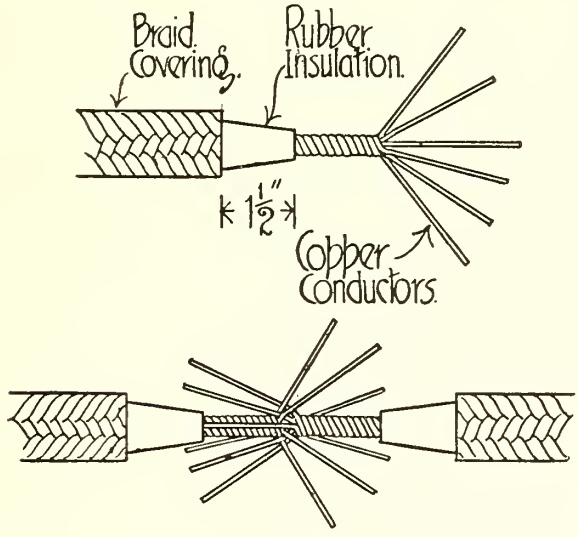


Fig. 135.

insulating material is cut back as with single wires, and the joint made in the same manner.

The method of jointing large stranded cables is different, and depends in some measure upon the number of the strands of which the cable is composed. Figs. 135 and 136 shows a joint between two cables composed of 7 strands each. The braiding is cut back to a distance of about 6 inches, and a shoulder is neatly

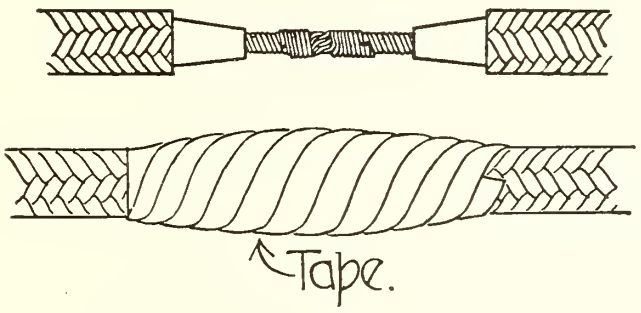


Fig. 136.

formed with a sharp knife. The rubber insulation is also cut back and neatly tapered to a conical form about 1½ inch in length. The copper wires are separated for a length of about 2 inches from the end, and carefully cleaned with emery cloth. The remainder of the exposed copper wires are twisted tightly together, and the central strand is cut out as close as possible to the point where the strands commence to separate, when the end of each cable will appear as shown in the upper part of Fig. 135. The strands are then "married"; that is to say, the separated strands of one cable are placed between the strands of the other cable, and the two twisted portions are pushed tightly together as shown in the lower part of Fig. 135. The separated strands of one cable are then twisted round the twisted strands, and *vice versa*, care being taken that the separated ends are twisted in the same direction as the twisted strands which they overlap. The joint now assumes the appearance shown in the upper part of Fig. 136, and is now ready for soldering. This should be performed rapidly, so that the insulation on either side of the joints may be affected as little as possible. Care should be taken that the solder thoroughly permeates the whole joint. Soldering is best performed with a soldering iron of good size, with a groove near the end of the bit in which the wires are placed during the soldering process. The joint is then laid in the groove, and resin is sprinkled upon it and the end of a strip of solder is placed upon that; the solder melts immediately and permeates the whole joint if the solder-

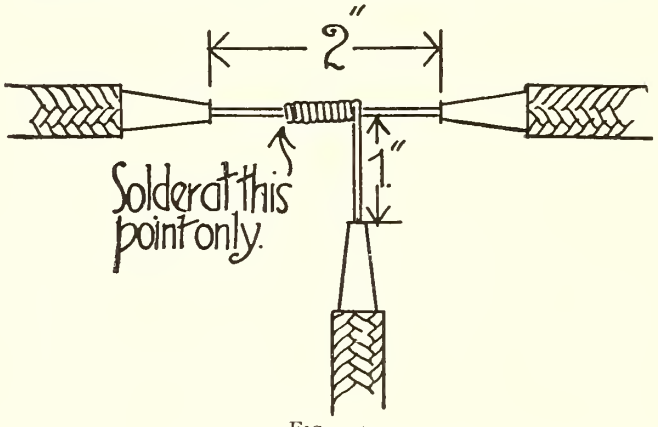


Fig. 137.

ing iron is at the correct temperature. No other flux but resin should be used, as others, such as acid or "killed-spirit," cause the copper to corrode. When the joint has cooled any irregularities should be trimmed off with a file. The joint is then insulated in the following manner:—Rubber solution is thoroughly rubbed over the exposed metal and insulation in not too large a quantity. Pure rubber strips are then tightly bound in at least two layers over the whole length of the joint, the layers being made to adhere by the application of a small quantity of rubber solution. In the best work six layers are employed. A small quantity of rubber solution is applied to the outer layer of rubber strip, to cause the subsequent protecting coat of tape to adhere to it. This tape is specially prepared for the purpose, and is applied in two layers thoroughly amalgamated with rubber solution. The application of rubber solution well rubbed in to the outer layer of tape completes the joint, which then presents the appearance shown in the lower part of Fig. 136.

When cables consisting of a large number of strands

are to be jointed it is found that these strands, by virtue of their number, become very unruly in the process of marrying. They are therefore bound together with fine copper wire at the points where the strands begin to separate.

Tee Joints.—When a tee joint is to be made in single wires, about 2 inches of the main cable and 2 inches of the branch cable are bared, the insulating material being treated as before described. The wires are cleaned, and about 1 inch of the branch is wound round the main cable, and soldered to it at the extreme end. It is found that if the whole coil of wire is soldered it becomes too stiff and brittle to permit the rubber strip to be bound round it or to enable the wires to be drawn into casing (see Fig. 137).

To join stranded cables in the tee form, about 5 inches of the main cable and 7 inches of the branch cable are bared. About 2 inches of the branch cable is twisted up, and the remainder of the exposed strands are divided into the form of a Y and laid side by side so as to form two flat strips, as shown at A, Fig. 138. The two horns of the Y are then wrapped round the main cables in opposite directions, as shown at B.

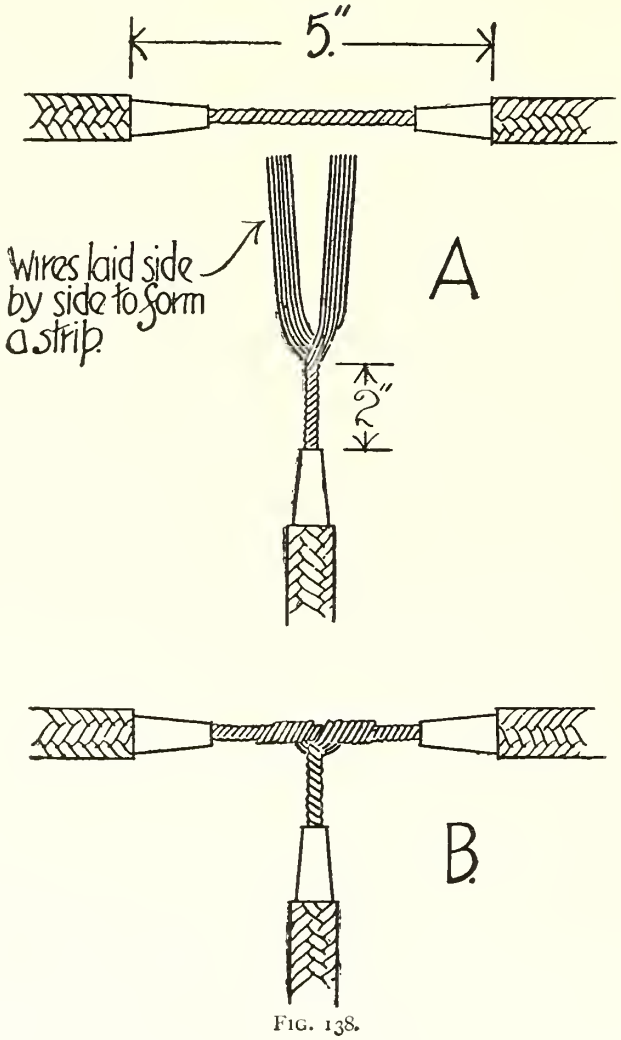


Fig. 138.

CHAPTER XVII

ARRANGEMENT OF CABLES AND CUT-OUTS IN A BUILDING

(*Contributed by H. Y. Margary*)

As in this and in the subsequent chapters a number of technical terms will be employed, such terms will be here fully explained save where they apply to fittings, when a general explanation will be given in this chapter, while a detailed description of the various forms and patterns will be given in the chapter upon "Accessories."

A Circuit means a system of conductors which will enable a current of electricity to pass through it.

A Switch is a contrivance for completing or breaking an electric circuit, and it is by means of a switch that a current may be allowed to flow or prevented from flowing in a circuit at will. The act of completing or "making" a circuit is called "switching on," and that of breaking a circuit is called "switching off."

A Fuse or cut-out is a contrivance for automatically cutting off a current from a circuit should too much current flow through it. The conductors in a building are of such a size that they can carry sufficient current to light the lamps with which they are connected. Should more current flow through the conductors than the amount they are intended to carry they become heated, thus destroying the insulating material and setting fire to any adjacent inflammable material. A fuse or "cut-out," which is composed of a piece of easily fusible wire, prevents this danger by melting when a current passes through it larger than it is intended to take.

A Short Circuit.—Any circumstance which allows the current passing through a conductor to increase without limit is said to short circuit the conductor. A short circuit occurs when metallic contact is made between the terminals of a lamp holder, or when, through faulty insulation of cables, electricity escapes to earth.

A Meter is a contrivance for measuring the amount of electrical power consumed by a number of lamps.

A Distributing Board is a contrivance for enabling the wiring of a building to be split up into a number of separate circuits.

If all the lamps in a large building are connected directly to the two supply mains, and should a short circuit occur, a very large amount of electrical energy will pass through the mains and probably cause a fire. To prevent short circuits being formed in buildings carrying very large currents, most supply companies have a rule that no wiring system in which there is a circuit carrying more than ten ampères will be connected with their mains. For this reason boards conveniently arranged for splitting the wiring into separate circuits are used, each circuit being protected by a separate fuse.

In Fig. 140 distributing boards are illustrated diagrammatically. They consist essentially of a slab of some incombustible material to which two strips of copper or brass, A, A, called "omnibus bars," or more commonly "bus bars," are attached. At the ends of these bus bars are binding screws B, B, for the connection of the house service mains. Connections are also made between the bus bars and smaller binding screws C,C, to which the separate circuits are connected. The main distributing board usually has separate switches for each circuit.

Systems of Wiring Buildings

There are three general systems of arranging the conductors within a building for electric lighting purposes. These are the *Tree or Single Main System*, the *Subdivided Main System*, and the *Three-Wire System*.

The Tree or Single Main System.—This system is diagrammatically illustrated in Fig. 139, from which it will be seen that the house mains, after passing through the main fuse, the main switch, and the meter, are taken straight through the house; and branches of the same size as the mains are taken from the mains at convenient places and connected to the main terminals of local distributing boards. This system should only be used in small buildings, as it is impossible to divide up the single mains for testing purposes, which makes it very difficult to localise a fault. The tree system is permissible when connected to a private generating plant, but it is usually prohibited by the regulations of a supply company.

Distributing boards are not always used with the tree system, the minor branch wires being simply jointed or connected by means of small fuse boxes to the branches, as shown in the right-hand top corner of the diagram.

Subdivided Main System.—In this system the mains, after leaving the meter, are carried to a main distributing board, from which separate smaller leads are taken to the local distributing boards, as shown diagrammatically in Fig. 140.

The advantages of this system are that each separate

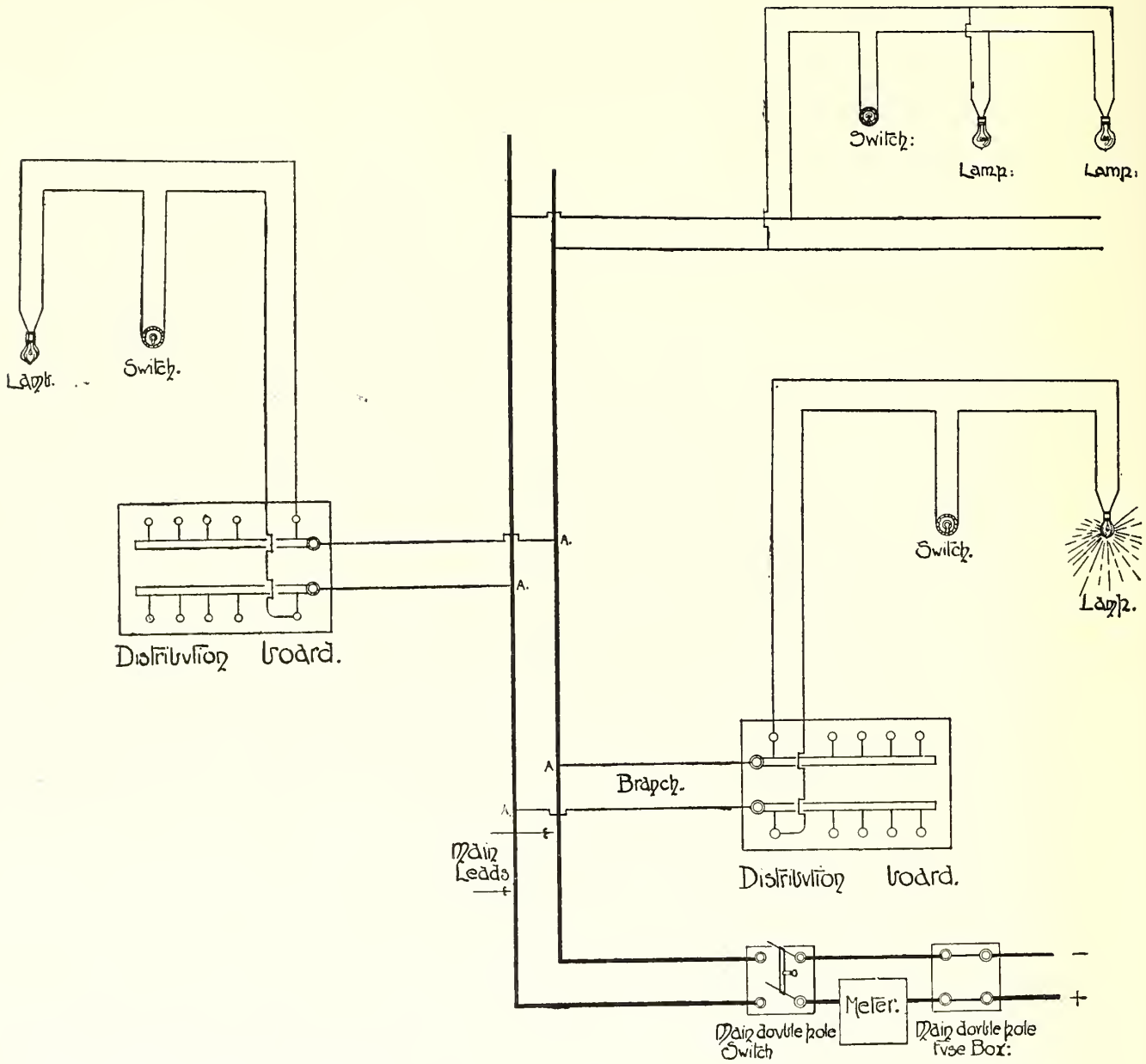

Switch.
Lamp.
Lamp.
Lamp.
Switch.
Lamp.
Switch.
A.
A.
Distribution Board.
A
A
Branch.
Main Leads
Distribution Board.
Meter.
Main double pole Switch
Main double pole Fuse Box.
−
+

FIG. 139.

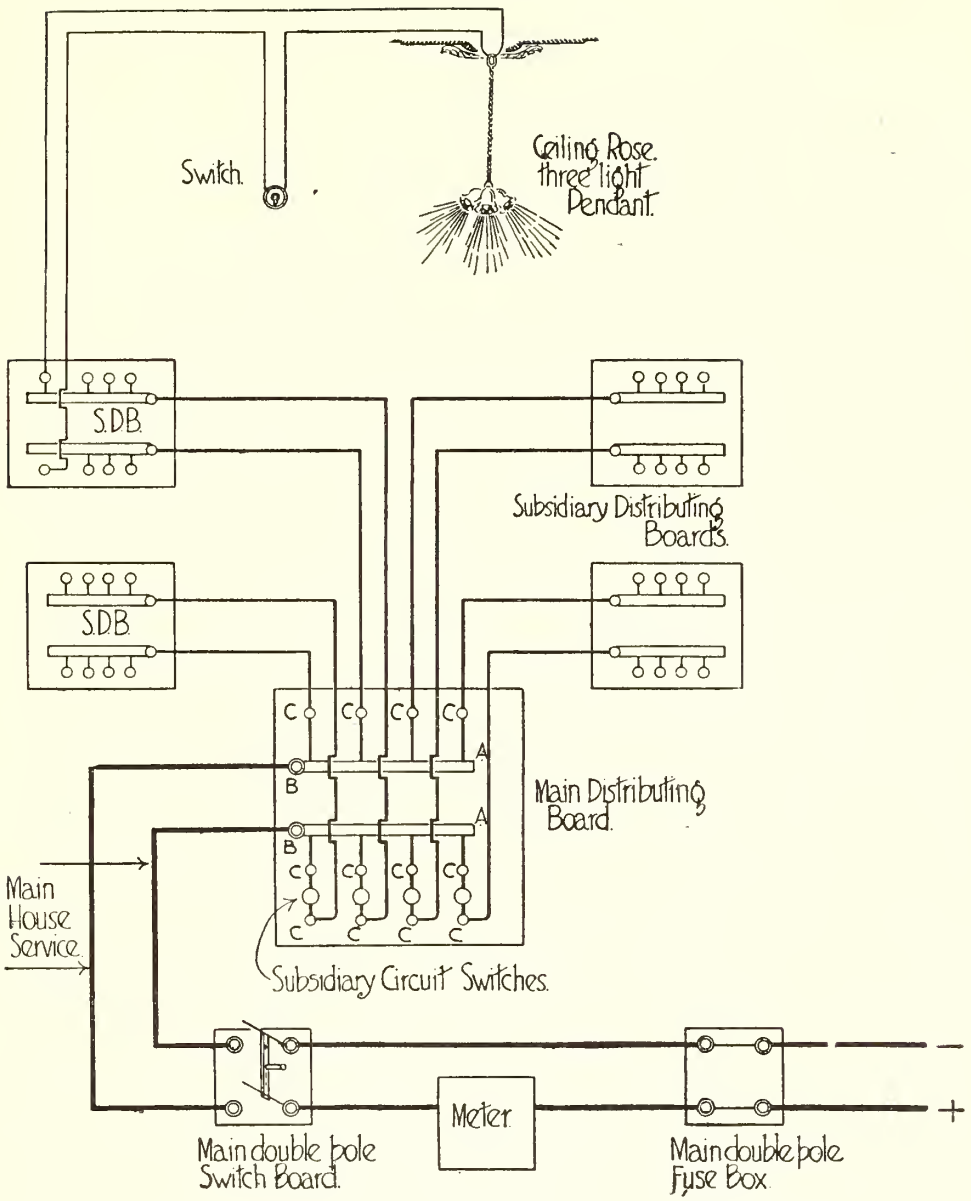

Switch.
Ceiling Rose.
three light
Pendant.
S.D.B.
S.D.B.
Subsidiary Distributing
Boards.
C
C
C
C
A
B
A
B
Main Distributing
Board.
C
C
C
C
C
C
C
C
Main
House
Service.
Subsidiary Circuit Switches.
Meter
Main double pole
Switch Board.
Main double pole
Fuse Box.
—
+

FIG. 140.

circuit may be readily tested and isolated at will; each circuit can be provided with a separate cut-out; and each circuit can be arranged to carry a limited current.

The Three-Wire System.—When the number of lamps to be lit reaches 100 or more it is often economical to employ the three-wire system. The advantages of this system may be explained by means of a few simple diagrams. Thus Fig. 141 represents two circuits of conductors and lamps supplied by two separate dynamos, each at, say, 100 volts pressure. If now the two dynamos be connected up in series the lamps may be fed by three cables instead of four, as shown in Fig. 142. If there be the same number of lamps on either side of the central or neutral wire, no current whatever flows through it. Where the three-wire system is used, therefore, it must be so arranged that the same number of lamps are likely to be switched on at the same time on either side of the central wire. As it is usually impossible to ensure this always occurring, there is usually a current flowing in the central wire, the amount of which is the balance of the amount flowing on the side with the most lamps switched on over the other side. The lamps can usually be arranged so that the current flowing in the central wire is never very great. For this reason the central wire is usually made smaller than the outside wires. The actual area depends upon the difference in the number of lamps which are likely to be switched on on either side of the central wire, but the central wire should rarely be less than one-third the sectional area of the outside wires.

The three-wire system of wiring may be applied to a building on lines somewhat analogous to the two two-wire systems already illustrated. Thus Fig. 143 shows diagrammatically the application of the three-wire system upon the tree system, in which the mains are taken through the building, and branches are taken from them to local distributing boards. The objections to this are the same as explained in connection with the single main system.

In large institutions, such as hospitals, where a number of buildings lie scattered about a large site, the three-wire system may be used with advantage in the external mains, but only as far as the main distributing board of each block of buildings. A suitable system is illustrated in Fig. 146. The advantage of this system lies in the saving of copper in the conductors, which in a well-arranged system amounts to nearly half; and also in the gain in pressure throughout the system, there being a difference of potential of 200 volts between the outer conductors,

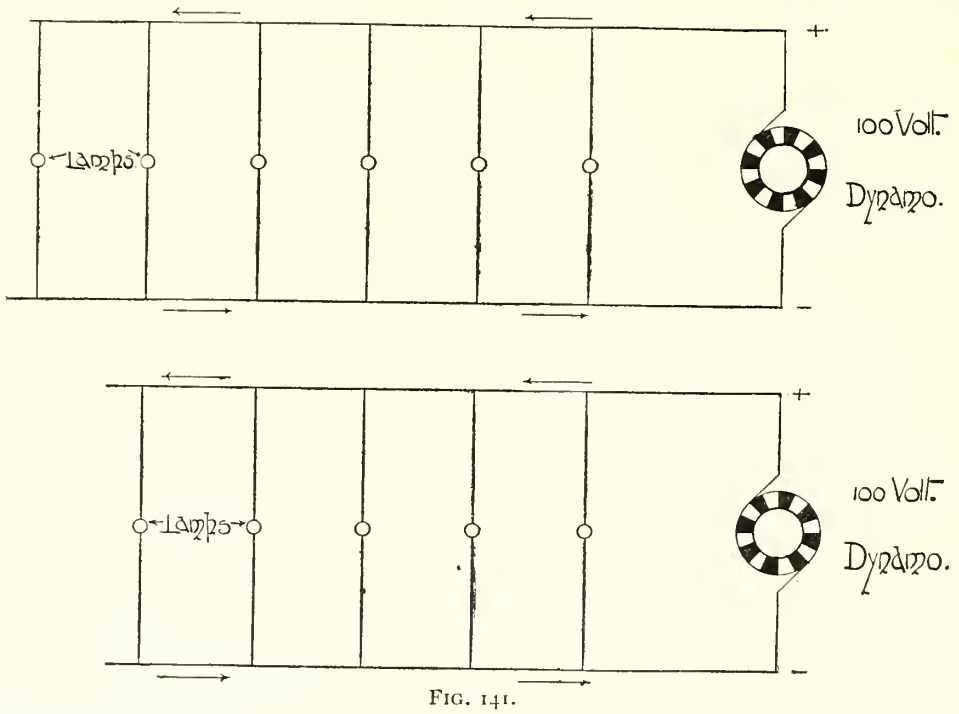


Fig. 141.

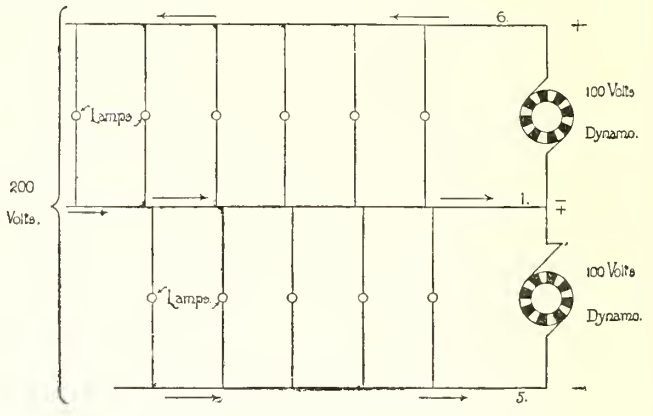


Fig. 142.

while the pressure across the lamps remains at 100 volts. It should be noted that with the three-wire system treble pole main switches and fuses should be used.

Position of Cut-outs.—In any wiring system it is advisable to place a cut-out at the junctions between thick and thin cables, so as to protect the latter against

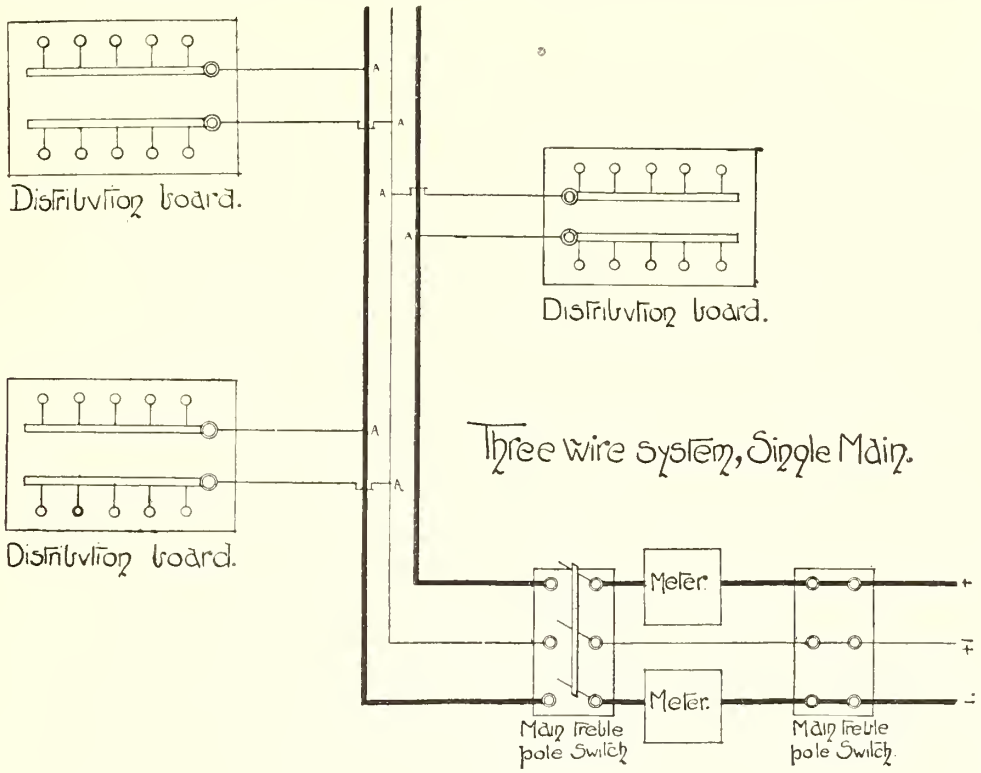


FIG. 143.

an excess of current, and care should be taken that the fuse is placed at the exact junction and not a little way along the thinner cable, as in Fig. 144, where it will be seen that, in the event of a short circuit across BD, or

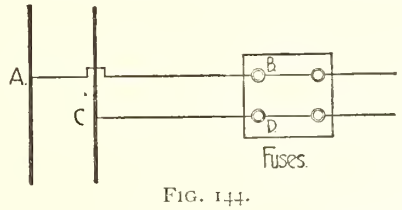


FIG. 144.

a leakage to earth from either AB or CD, those wires will fuse and perhaps cause a fire.

METHOD OF CONNECTING LAMPS

Incandescent lamps should always be connected up in *parallel* or *multiple*; that is to say, one wire connects one terminal of each lamp to one bus bar, and another wire connects the other terminal of each lamp to the other bus bar. Incandescent lamps are rarely connected up in *series*; that is to say, in such a manner as to have one circuit passing through a row of lamps, because the breakage of the filament of one lamp would cause the whole row to go out.

There are two distinct ways of connecting lamps up in parallel across the bus bars of a distributing board. In one each lamp has a separate pair of conductors, as at A and B, Fig. 145, or each group of lamps has a separate pair of conductors, as at C. In the other method a single or common wire connects one terminal of each lamp to one bus bar, while separate wires

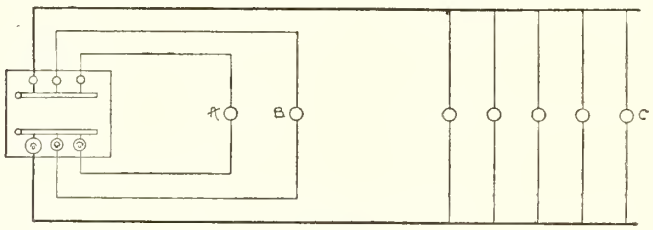


FIG. 145.

connect the other lamp terminals to the other bus bar, as shown in Fig. 147. These separate wires are called the "switch" wires, as they are connected to the switches so that each lamp may be switched on separately.

Staggering Lights.—When a room is lit by a number of lamps arranged in rows, and it is convenient to arrange the lights so that they may be switched on in groups, the lights are frequently wired as shown in Fig. 148, where it will be seen that alternate lamps in each row are controlled by one switch, so that

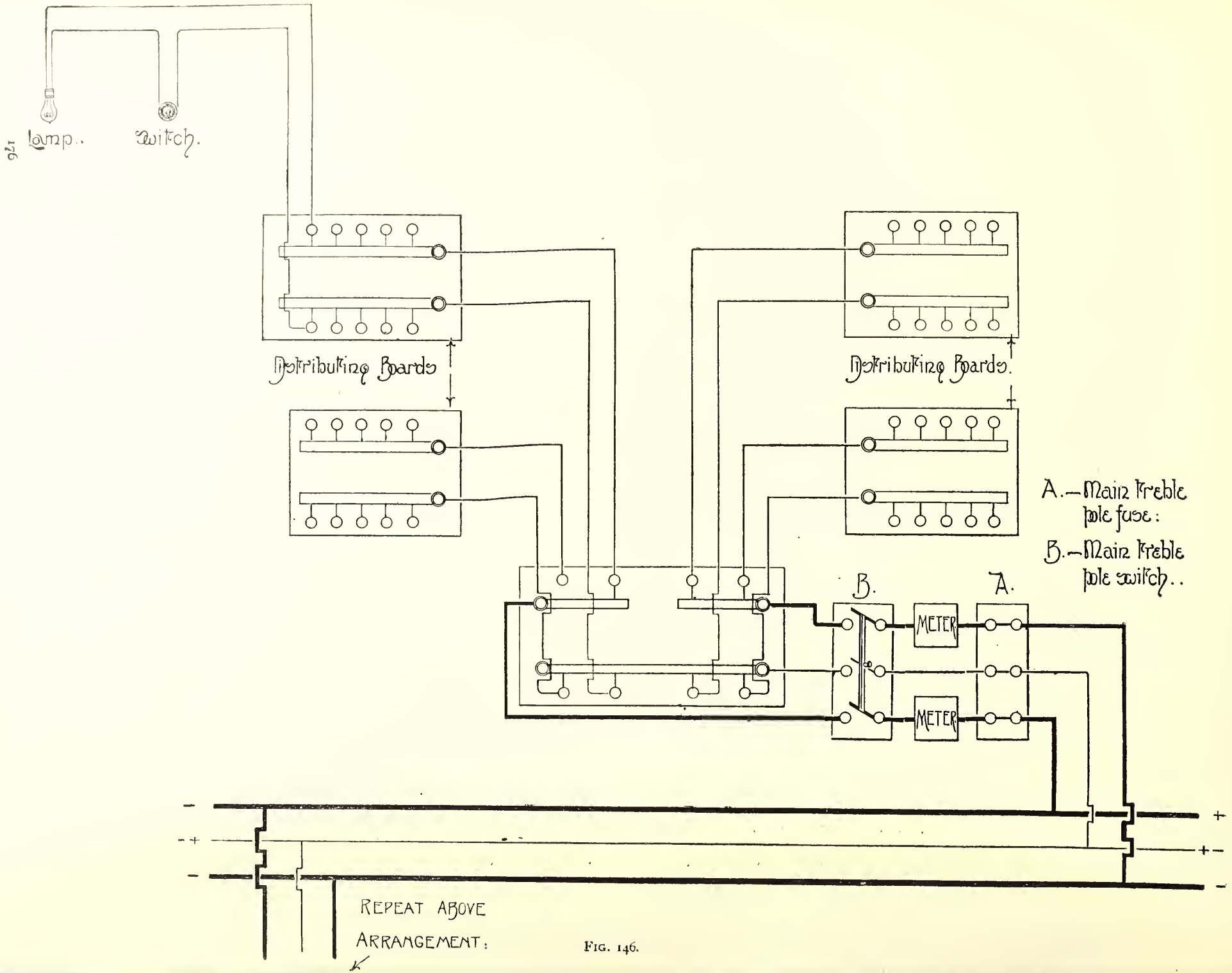
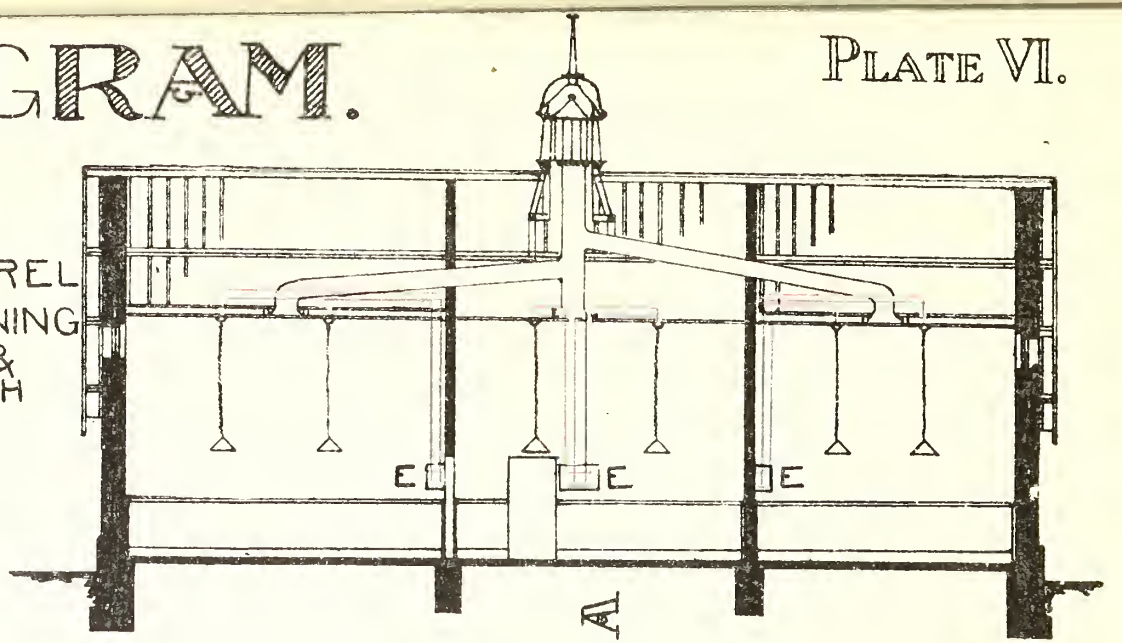

Lamp.
Switch.
Distributing Boards
Distributing Boards.
A.—Main treble pole fuse:
B.—Main treble pole switch..
B.
A.
METER
METER
REPEAT ABOVE ARRANGEMENT:

FIG. 146.

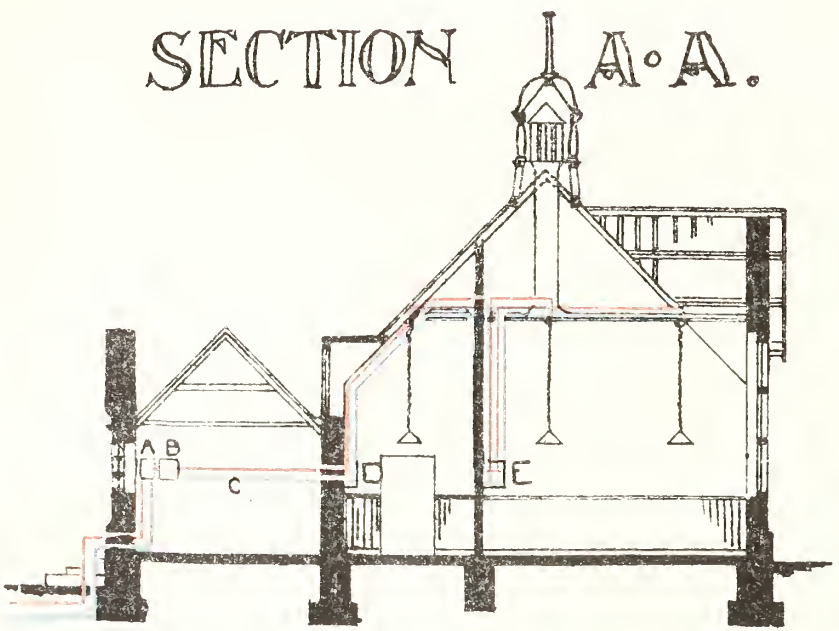
WIRING DIAGRAM.

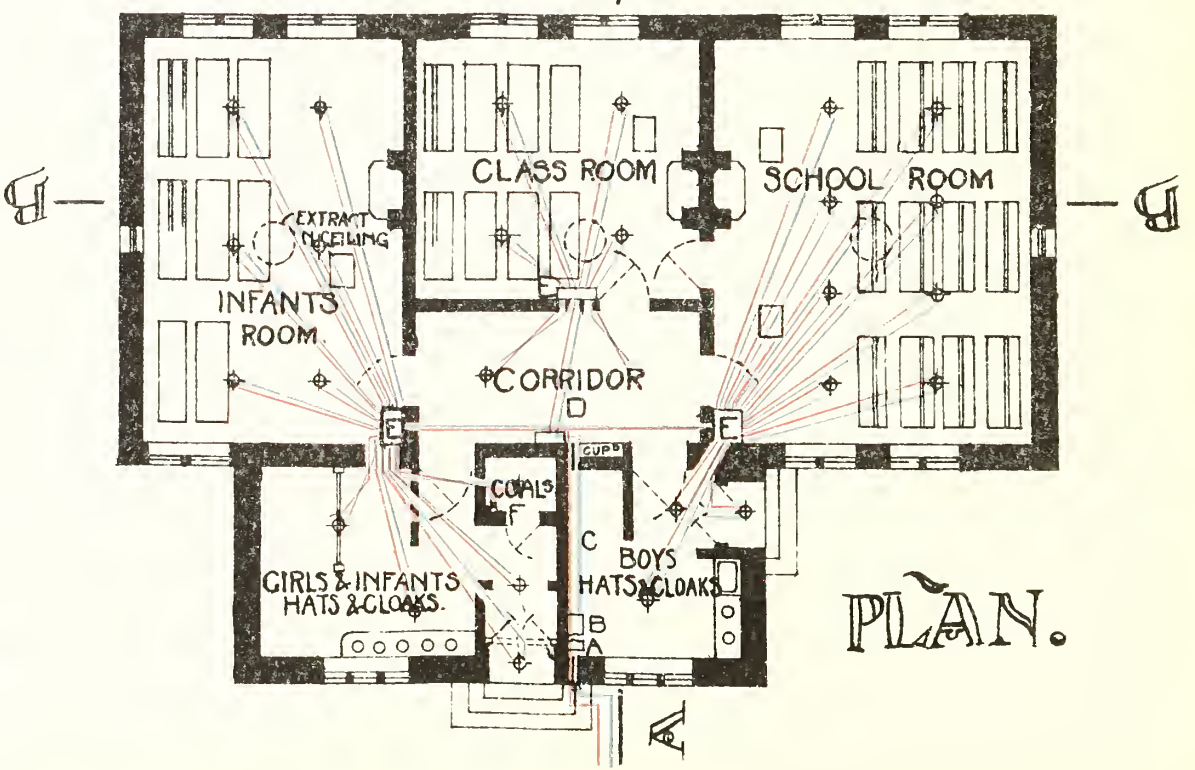
A. MAIN DOUBLE POLE FUSE.
B. METER
C. HOUSE MAIN ENCASED IN BARREL
D. MAIN DISTRIBUTING BOX CONTAINING MAIN DOUBLE POLE SWITCH, & A DOUBLEPOLE FUSE FOR EACH SUB-MAIN.
E. SUBSIDIARY DISTRIBUTING BOX CONTAINING ONE SINGLE POLE SWITCH & FUSE FOR EACH LAMP CIRCUIT.
F. SWITCH FOR LIGHT TO COALS.
⌖ POINTS OF LIGHT.



SECTION B·B.

SECTION A·A.





PLAN.

should one fuse "blow" the room is not thrown in complete darkness, and the lamps left burning are well distributed.

Looping out.—Wherever possible it is advisable not to make joints in cables, and joints can usually be avoided by a method known to the trade as *Looping out*. On referring to Figs. 139 and 143 it will be seen that a joint is shown at the points A, A, A. These joints may be avoided by taking up loops in the

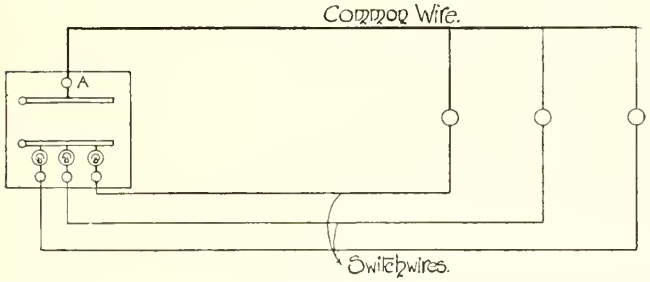


Fig. 147.

main cables and connecting the ends of the loops to the terminals of distribution or fuse boards, as shown in Fig. 149. All fittings, such as lamp holders, ceiling roses, fuse boxes, etc., are made with large terminals to permit this system of looping out to be applied to them. In the lower portion of Fig. 150 a number of lamps are shown connected to a pair of leads by jointed branches on to them as at A, A, while the upper diagram shows the method of avoiding joints by the system of looping out.

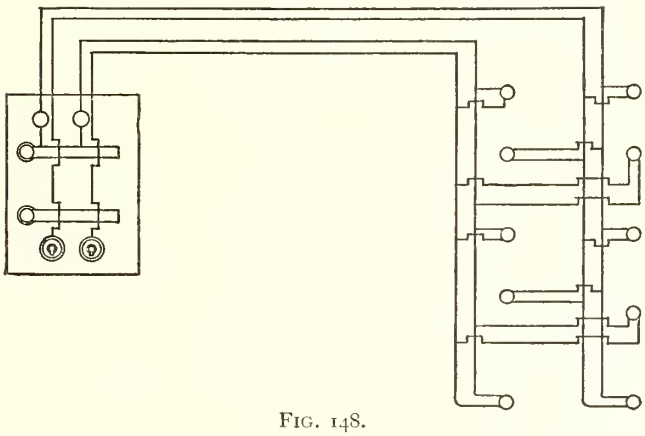


Fig. 148.

Example of Wiring a Building

In Plate VI. is illustrated the plan and sections of the school previously described in Fig. 1, with the arrangement of wires for electric lighting shown upon it diagrammatically.

The number of lamps in any building usually depends upon the building owner's wishes, but when he does not decide this point the architect or electrician should decide for him. Calculations for the number of lights are usually based upon the number of 8 candle-power required to light 100 superficial feet of floor space. The following table will give an approximate idea of

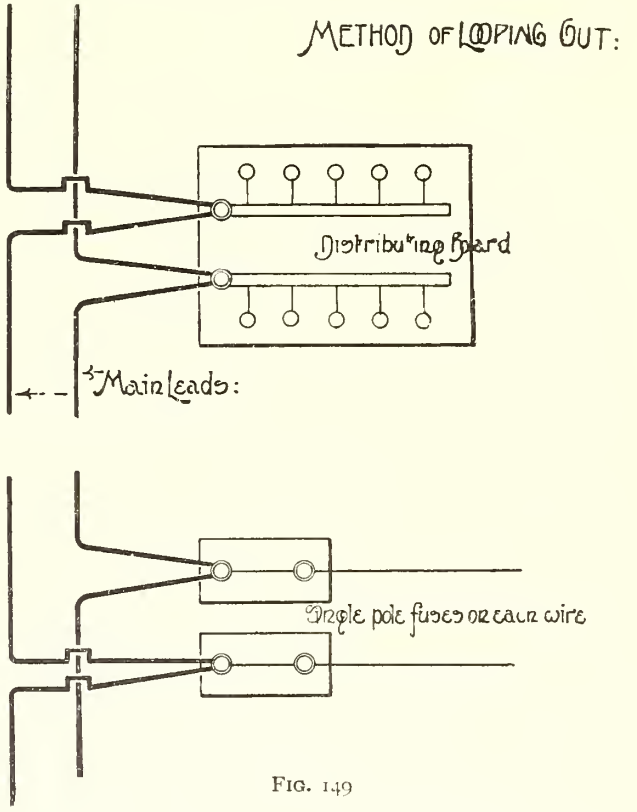


Fig. 149

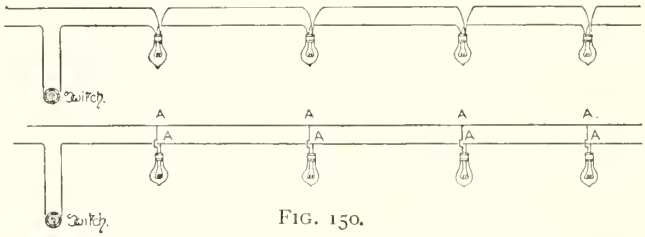


Fig. 150.

the number of lights required for ordinary purposes at a height of 7 feet 6 inches above the floor level:—

Description of Room.	Number of 8 c.p. Lamps per 100 Square Feet of Floor Area.
Lecture-rooms, music-rooms, entertainment halls, schoolrooms, etc.	4
Dining-rooms, drawing-rooms, principal halls, staircases, and landings	3 to 4
Showrooms for the display of goods	3 to 4
Workrooms	3
Churches, chapels, shops, warehouses	2
Bedrooms, minor rooms of residences, small passages, etc.	1

The higher the lights are placed above the floor level the less, of course, will be their illuminating effect, and it is usually reckoned that an 8 c.p. lamp placed 7 feet 6 inches above the floor level will have the same illuminating effect as a 16 c.p. lamp 12 feet above the floor level.

A rough and ready rule for the number of lights in a dwelling-house is to allow 3 c.p. of light per 10 superficial feet of floor space.

In the school illustrated in Plate VI. the right-hand schoolroom has a floor space of 590 square feet. The number of 8 c.p. lamps required to light it, according to the above table, will be—

$$\frac{\text{Area of floor} \times 4}{100} = \frac{27'.\,3'' \times 21'.\,9'' \times 4}{100} = 24.$$

The central classroom requires fourteen 8 c.p. lights, and the infants' classroom twenty 8 c.p. lights.

These powers can be approximated most nearly by the use of 8 c.p. lamps arranged in clusters of three lamps, thus:—

Right-hand classroom, 2 rows of 4 clusters of 3 lamps = 24 lamps.								
Central classroom	2	,,	2	,,	3	,,	12	,,
Infants' classroom	2	,,	3	,,	3	,,	18	,,

The lamps are arranged as pendants at a height of 7 feet 6 inches from the floor, this height being well out of the reach of the children and convenient for even diffusion without unnecessary loss of light.

The reason for using 8 c.p. is that lamps of this candle-power lend themselves better to a symmetrical arrangement and more equal diffusion than lamps of any other power for the particular example treated.

It is very necessary that schoolrooms should be amply lit with well-diffused light, and the walls should be of a light colour to assist in the general diffusion of light, so that the shadows may be as light as possible.

The corridor need not be so well lit as the classrooms, for which reason two pendants of three lights each have been used, allowing approximately three 8 c.p. lamps per 100 square feet of floor space.

The girls' cloakroom is lit by two 8 c.p. lamps—one in the centre of the room, and one over the lavatory basins. The boys' cloakroom has only one light, placed approximately centrally. Two 8 c.p. lights are placed in the front entrance, and one in the side entrance. One 8 c.p. light is placed outside each entrance, to guide the children to the doors in dark or foggy weather, and to prevent them from stumbling on the steps. One 8 c.p. light is also placed inside the coal-store, and is controlled by a switch just within the coal-store door.

All the lights, save the coal-store light, are controlled from switches fixed to the subdistributing boards in the classrooms. These distributing boards are encased, so that they are out of the way of the children, and can only be touched by the mistresses or masters who possess the keys to the cases.

The lights in the entrances are fixed near the ceiling, well out of reach of the children.

Arrangement of Cables.—The supply is brought in at the most convenient point to the supply company's mains, and carried through the main fuse and meter to the main distributing board, where the mains are connected to the terminals of the main switch before the bus bars are reached. Separate leads are taken from the terminals of the main distributing board to the bus bars of the subsidiary distributing boards. Separate circuits are then taken from these to each cluster and to each separate lamp. It would, of course, be more economical at the outset to so arrange the lights that they might be switched on in groups, but this often necessitates great waste of current. In the right-hand classroom, for instance, if each row of four lights were controlled from one switch only, it would mean that on occasions when one cluster would afford ample light, four clusters at least would have to be switched on.

All wires are taken by the shortest routes from point to point, unless for appearance sake they must be taken otherwise. Thus when cables are concealed within wooden casing fixed to the walls it is usual to fix the casing either vertically or horizontally, although very frequently economy might be effected by running the casing and cables diagonally.

In the case under consideration it is assumed that wood casing is to be used, and the shortest routes from point to point in every case will be obtained by taking the cables vertically up to the roof, diagonally in the roof, and vertically down again.

The Sizes of Cable required is governed by the amount of current they are to carry. Lamps of 8 c.p. usually require about 30 watts to run them, so that, assuming the pressure of the supply to be 100 volts, it follows from the formula $C \times V = W$ that

$$C = \frac{30}{100} = 0.3 \text{ ampères.}$$

Each cluster of three lamps will take 0.9 ampères, and in referring to Column 4 of the table given on page 180 it will be seen that the smallest stranded cable will carry a current of 4.4 ampères, so that it will be perfectly safe to use 3/22 cable in this case for all the circuits from the subsidiary distributing boards through the lamps.

The size of the sub-mains must now be determined. The current flowing in the sub-main on the right-hand side, when all the lamps on this particular circuit are switched on, will be 27×0.3 ampères $= 8.1$ ampères, and the smallest size of cable which will carry this current is 7/22 (see Table). The central and left-hand sub-mains carry 5.4 and 6.9 ampères respectively, so that smaller cables might be used for these; but in practice they are usually made of the same size as the main carrying the largest current. The house main, of course, carries the sum of the currents in the sub-mains, namely, $(8.1 + 5.4 + 6.9) = 20.4$ ampères, and the

smallest cable to carry this current is given by the table as 7/18.

Distributing Boards.—The main distributing board contains six fuses, one for each pole of the three sub-mains, and may be of any of the types shown in Chapter XIX., where the method of connecting to the circuits is also shown. The subsidiary distribution boards contain fuses and switches, one fuse on one pole of each circuit and one single-pole switch on the other pole of each circuit. The lamps are hung from ceiling roses by means of flexible wire, composed of two cables of 35/40 twisted together. The size of this flexible wire is determined from the following table, where it will be seen that the smallest wire which will safely carry 0.9 ampères is 35/40:—

TABLE OF FLEXIBLE WIRES.

Stranded Copper Wire.	Equivalent in Single Wire.	Carrying Capacity. Ampères.
23/40	22	0.6
35/40	20	1.0
70/40	18	1.8
130/40	16	3.2

Sizes of Fuses.—The size of a fuse wire depends upon several points, namely, the distance between the fuse terminals, the size of the fuse terminals, the material of which the fuse is made, and the current to be carried by the circuit which the fuse is to protect from overheating.

The distance apart of the terminals is not, as a rule, worth considering, as the fuse boxes are designed for various currents and voltages. The size of the terminals also affects the blowing of fuses according to the rate at which they carry away the heat generated by the passage of excessive currents, but this is a point which need not be considered as a rule, as the sizes of these accessories are standardised.

The material of which the fuse wires are made is a very important one, as may be seen from the following table. Still more important in determining the size of the fuse wire is the current it is required to carry. The following table gives the approximate fusing points of fuse wires of lead, tin, and copper.

Fuse wires are usually of such a gauge that they will "blow" when the current becomes 50 per cent. greater than that which the circuit it protects is intended to carry.

Approximate fusing Current in Ampères.	Approximate Standard Wire Gauge.		
	Tin.	Lead.	Copper.
1	37	35	47
2	31	30	43
3	28	27	41
4	26	25	39
5	25	23	38
10	21	20	33
15	19	18	30
20	17	17	28
25	16	15	26
30	15	14	25
35	14	13	24
40	14	13	23
45	13	12	22
50	13	12	21
60	12		21
70			20
80	Strip fuses	Strip fuses	19
90	above this	above this	18
100	Gauge.	Gauge.	18
120			17
140			17
160			16
180			16
200			15
225			14
250			14
275			13
300			13

Note.—Pure copper wire (Column 4) makes the most reliable fuse, and must be at least 1 inch in length, measured between the terminal clips.

Thus in Plate VI. the separate lamp circuits carry 0.9 ampères, so that the fuses should blow when a current of 1.35 ampère passes through it. The wires for these circuits are 3/22, and will actually carry a current of 4.4 ampères (see table, page 180), so the fuses might be such a size as to blow when 6.3 ampères passed through them. The fuse wires in this particular case may be of tin of any gauge between 31 and 25 S.W.G. The sub-mains are all of 7/22 wire, which will carry a current of 8.7, and the fuses should blow when a current of 13.05 ampères passes. The wire for the purpose will be of tin No. 21 S.W.G.

The mains carry a current of 20.4 ampères, so that the fuse must blow at 30.2 ampères when No. 25 S.W.G. copper wire will be used. The main fuse, which is usually inserted by the supply company, is generally made of copper, and all the fuses on the branches are of lead or tin.

TABLE SHOWING MAXIMUM CURRENTS, THICKNESS OF DIELECTRIC AND INSULATION RESISTANCE FOR COPPER CONDUCTORS, INSULATED AND LAID IN CASING OR TUBING.

ISSUED, JULY 1896, BY THE INSTITUTION OF ELECTRICAL ENGINEERS.

1 Size of S.W.G	2	3	4	5	6	7	8	No. of 8 p.c. 30 Watt Lamps at 100 V.	No. of 16 c.p. 60 Watt Lamps at 100 V.	No. of 16 c.p. 60 Watt Lamps at 220 V.	Size of Casing.	Width of Grooves.
											Inches.	Inch.
18	3·1	23	4·2	18	35	1200	300	14	7	15	$1\frac{1}{4}$	$\frac{3}{16}$
3/22	3·3	23	4·4	17	36	...	...	15	7	16	...	...
17	4·0	25	5·4	19	36	...	...	18	9	20	$1\frac{1}{2}$	$\frac{1}{4}$
3/20	4·8	26	6·6	19	38	...	...	22	11	24	...	...
7/22	6.2	28	8.7	20	38	...	...	29	14	32	...	...
$7/21\frac{1}{2}$	7.0	29	9.8	21	38	...	...	33	16	36	$1\frac{3}{4}$	$\frac{5}{16}$
3/18	7·5	30	11.0	20	40	600	...	36	18	40	...	...
7/20	9·3	31	13.0	22	41	...	...	43	22	48	...	...
7/18	14.6	37	21.0	25	44	...	...	70	35	77	2	$\frac{3}{8}$
19/20	20.6	39	30.0	26	48	...	...	100	50	110	$2\frac{1}{2}$	$\frac{1}{2}$
7/16	23.0	40	34.0	27	49	...	...	113	51	125	...	...
19/18	31.0	45	48.0	29	54	...	...	160	80	176	3	$\frac{5}{8}$
7/14	32.0	45	49.0	29	54	400	...	163	82	180	...	...
19/16	49.0	51	77.0	32	62	...	...	256	128	283	$3\frac{1}{2}$	$\frac{3}{4}$
19/14	70.0	56	110.0	35	70	...	...	366	183	402	4	$\frac{7}{8}$
37/16	83.0	59	130.0	37	75	...	...	433	217	476	$4\frac{1}{2}$	...
19/12	100.0	66	170.0	39	82	300	...	566	283	623	5	1
37/14	120.0	64	190.0	40	86	...	...	633	317	695	...	...
61/15	150.0	67	240.0	42	95	...	...	800	400	880	$5\frac{1}{2}$	$1\frac{1}{4}$
61/14	170.0	74	290.0	43	102	...	...	966	483	1060	...	...
37/12	180.0	73	300.0	44	103	...	...	1000	500	1100	...	...
61/12	260.0	82	450.0	47	124	...	...	1500	750	1650	6	$1\frac{1}{2}$
91/12	350.0	90	620.0	51	144	...	...	2066	1033	2270		
91/11	420.0	94	740.0	53	158	...	...	2466	1233	2700		

EXPLANATION OF TABLE.

COLUMN 1.—Gives the sizes of the conductors in common use. Cables are shown thus:—19/14, namely, 19 wires of No. 14 Standard Wire Gauge.

COLUMN 2.—Gives the maximum current for situations where the external temperature is above 100° F. The maximum rise in temperature will be about 10° F. on large sizes.

COLUMN 3.—Gives the total length in yards of lead and return of each size of conductor causing a drop of one volt, when transmitting the current shown in Column 2.

COLUMN 4.—Gives the maximum current allowable in any situation. The maximum rise in temperature will be about 20° F. on large sizes.

COLUMN 5.—Gives the total length in yards of lead and return of each size of conductor causing a drop of one volt, when transmitting the current shown in Column 4.

COLUMN 6.—Gives the minimum thickness of dielectric. This may be obtained for any conductor by adding 30 mils. to $\frac{1}{10}$ the diameter of the conductor.

COLUMNS 7 AND 8.—Give the insulation resistances in megohms for one mile of cable of Classes A and B respectively.

A.—Those insulated with a material, as a dielectric, which is itself so impervious to moisture that it only needs further protection from mechanical injury or from vermin. B.—Those insulated with a material, as a dielectric, which, in order to preserve its insulation qualities, must be kept perfectly dry, and therefore needs to be encased in a waterproof tube or envelope, generally of soft metal, such as lead, which is drawn closely over the dielectric.

The numbers of lamps given are based upon the current densities in Column 4. If the cables or wires are to be used in situations where they will normally be subjected to a greater temperature than 100° F.—*e.g.* in drying-rooms, hothouses, etc., the maximum permissible number of lamps will be less than that given in the above table, and may be ascertained by dividing the current density (Column 2) by the current required for each individual lamp. For example, a 16 c.p. 60 watt 100 volt lamp requires $\frac{60}{100} = 0{\cdot}6$ ampères, assuming the number of such lamps permissible on 3/20 lead to be required; from Column 2, $4.8 \div 0.6 = 8$ lamps.

CHAPTER XVIII

CASING AND CONDUITS

(*Contributed by H. V. Margary*)

Having discussed the general arrangements of wires in a building, it is now necessary to describe the various methods of fixing the wires. These depend upon the nature of the wire and the conditions under which it is to be fixed. Wires which have an outer covering of lead drawn over them are frequently fixed by means of wood cleats, or small metal staples or straps nailed to any convenient woodwork. This method, of course, would only be used where appearance is no object, or where the wires could be successfully hidden by projecting mouldings.

Casing.—By far the most usual method of fixing wires is that of casing them, the wires being run in grooves formed in strips of wood fixed to walls or ceilings and covered with other strips of wood called capping, as shown in Fig. 151. The advantages of this system are that the casing is easily fixed, the wires can be easily inserted in the casing, and can be easily repaired when necessary. It is also very cheap, and offers sufficient mechanical protection to the wires when it is not subjected to rough wear.

When lining is required in damp situations, or subjected to rough wear, or where its appearance would destroy the general scheme of decoration, it cannot be used, and the wires would be concealed within the wall in steel conduits as hereafter described. Casing is usually made of American white wood, and that only should be used which is free from knots and shakes and possesses a good straight even grain. The capping should not be too thin, especially when of narrow widths, else it will warp, causing unsightly joints and exposing the wires.

Casing is usually made with too grooves, and varies from about $1\frac{1}{4}$ to 6 inches wide, the grooves being of a suitable width to take the various sizes of wires in common use (see table, p. 180). One wire only should be placed in each groove, but very frequently several wires are placed in one groove, or "bunched" as it is called. When this is done, however, the wires should be of the same polarity, so that any flaw in the insulation may not cause a short circuit. Where a number of wires are to be carried in one position, casing is sometimes made with a suitable number of grooves, but more often the necessary number of grooves is provided by fixing several rows of casing side by side.

The grooved portion of the casing is usually fixed with nails or screws to plugs or fixing blocks, and the capping is always screwed on so that it can be easily removed when necessary. The screws are usually fixed at a distance of from 18 to 20 inches apart, and when the casing does not exceed 2 inches

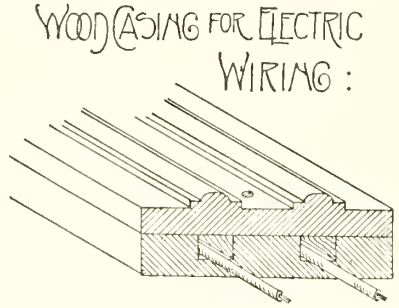


Fig. 151.

in width they are placed at the centre, as shown in Fig. 151. For larger sizes of casing the capping is fixed with screws inserted at both edges.

Before the wires are inserted in the grooves the

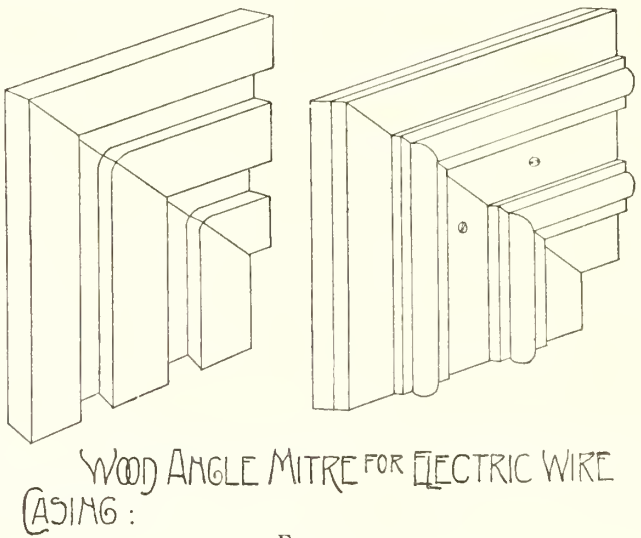


Fig. 152.

casing should be thoroughly well varnished with shellac varnish, especially where joints or mitres occur. The standard sizes of casings and the grooves suitable for standard cables are given in Columns 12 and 13 respectively of the table on page 180.

Where angular junctions occur the portions of casing should be neatly mitred together (see Fig. 152), and the grooves should be rounded off with a sharp chisel so that there may be no sharp edges for the wires to chafe against, and the wires may follow an easier curve. When a tee junction has to be formed in the casing, as, for instance, to bring the wire down to a switch or wall bracket, a double mitre is formed, as shown in Fig. 153. The capping is usually moulded in such a manner that these mitres make the mouldings mitre properly, as shown in Figs. 151 and 152, and when two lines of casing cross one another a double tee joint similar to that shown in Fig. 153 is sometimes used. This is considered by many to be a bad practice, for although it keeps the joint neat and level, it invariably necessitates the crossing of wires of opposite polarities. To avoid this one line of casing is bridged over the other, as shown in Fig. 154.

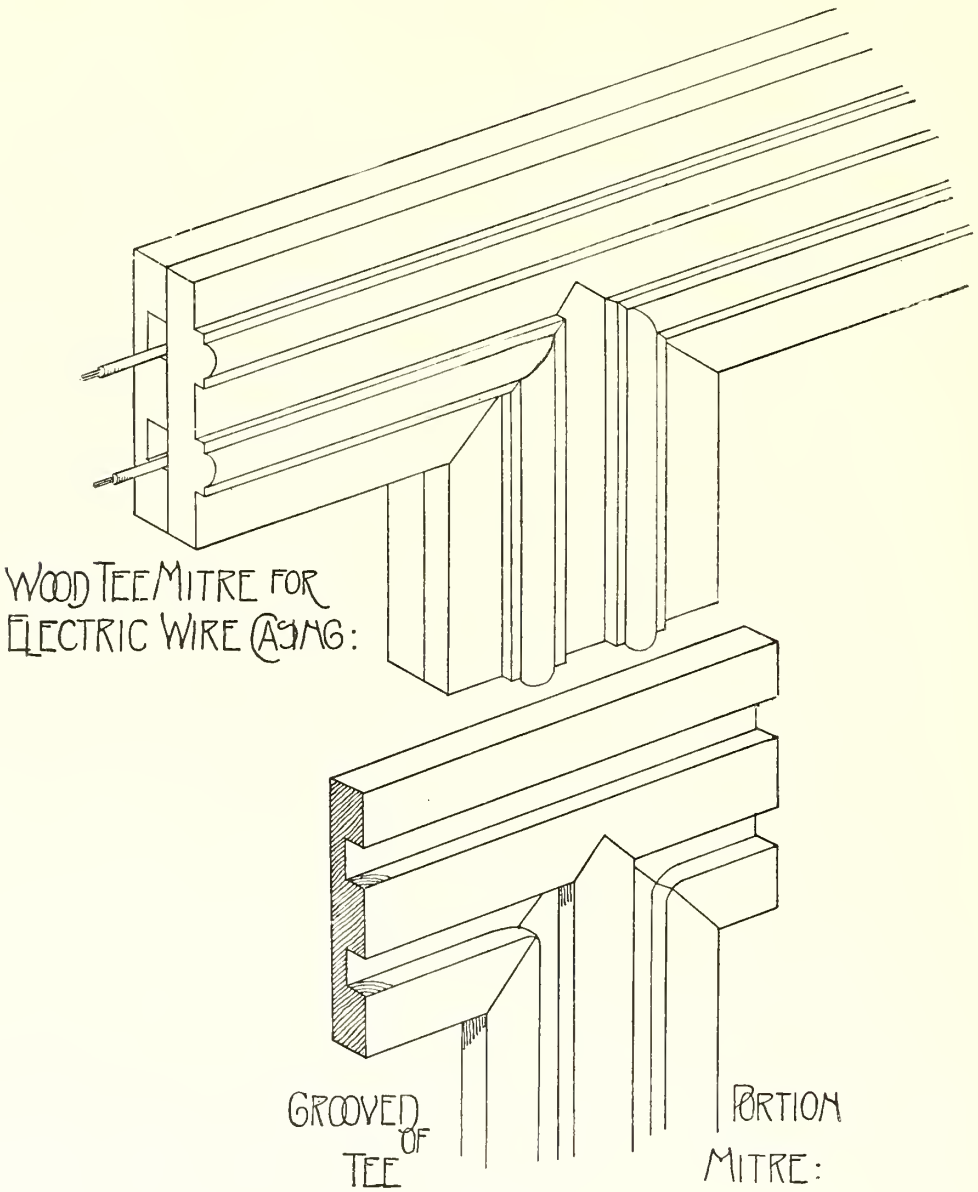


Fig. 153.

Conduits are tubes of papier-mâché, brass, or steel used for protecting the conductors of an installation. The system explained here is the "Armaduct" steel conduit, as this is one of the best forms at present on the market. The tubes are made in six different varieties, known as "Standard," "Extra heavy," "Seamless," "Seamless extra heavy," "Ordinary close joint," and "Galvanised."

"Standard" is welded mild steel tube, and is of such a nature that it can be readily bent or threaded at the ends. Steel tubes of this class are cleaned by a patent process, and coated inside and out with a superior insulating flexible moisture and acid-proof enamel, which preserves the metal from rust and oxidation,

and prevents its corrosion by the acids and alkalies contained in plaster and cement. The enamel has such tenacity that it does not flake or chip when the tube is bent, and decorative paint can be applied to it without discoloration. The interior of the conduit is treated in such a manner that it has a gun-barrel smoothness, which enables the conductors to be drawn in without abrasion of the insulation.

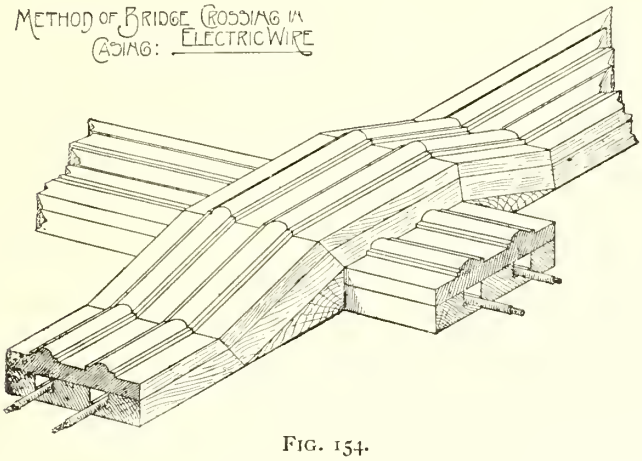


FIG. 154.

The "Extra heavy" quality is identical with the "Standard," with the exception that the gauge of the metal is that of "Standard gas barrel," namely, 14 to 9 S.W.G. This is employed for work subject to very heavy wear, or in very damp situations, such as docks and harbour work, iron works, foundries, chemical works, ice-making and cold-storage plants, breweries, laundries, and underground work. The "Seamless" quality is identical with the "Standard" in gauge and finish, but steel tube of the solid (cold) drawn quality is used in its manufacture. Solid tubes of this quality

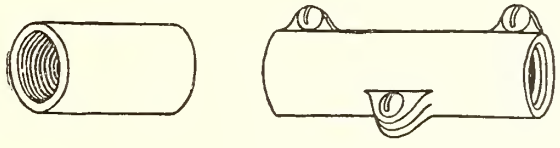


FIG. 155.

find favour with many consultants. The "Seamless extra heavy" quality is identical with the "Extra heavy" quality, but is manufactured from solid drawn steel tube.

The "Ordinary close joint" quality, as its name implies, is tube made from steel plate, with the joint or seam made as close as possible without welding. It is finished and enamelled similarly to the other qualities, but can only be used in dry situations.

Galvanised steel tube finds favour with some engineers, so this class of conduit is manufactured to meet the demand.

It will be seen, therefore, that conduits may be obtained to suit practically all possible conditions.

Coupling Sockets.—Lengths of steel conduits are connected together by means of steel coupling sockets of either of the patterns shown in Fig. 155, where it will be seen that one description of socket is made in two pieces, so that it can be taken off and the wires withdrawn from the conduit to repair the insulation, or to draw in more wires at any time, or they may be

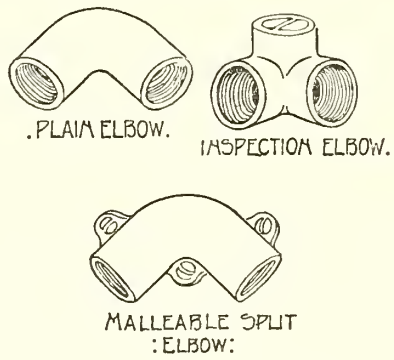


FIG. 156.

used in positions where it is difficult to screw the lengths of tube into them.

Elbows.—When conduits have to be carried round angles the tubes themselves may be bent, if the curve

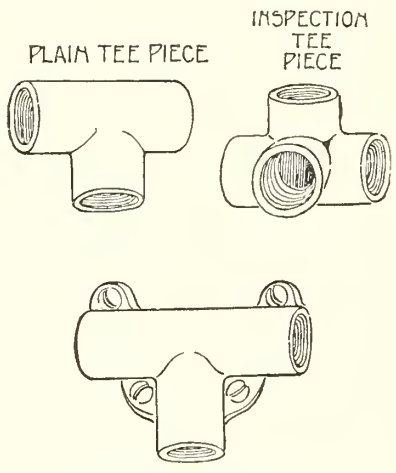


FIG. 157.

is a gradual one, but when the curve is sharp elbows as shown in Fig. 156 are used. These may be either plain, split, or may have a third limb cast on to them so as to facilitate the drawing in of the cables. The third limb is closed by a removable screw plug.

Tees are also made of the plain, split, and inspection type, as shown in Fig. 157.

Drawing in the Wires.—There are two methods of drawing in the wires: one where the whole system of conduits is first fixed in position; and the other where

the wire is drawn into sections of the conduit as the fixing of the conduit proceeds.

When the whole system of conduit is fixed in position, some means of drawing the cables into tubes must be afforded. This is done by fixing *draw-in boxes*, such as shown in Fig. 158, or *junction boxes* as shown in Fig. 159, at suitable places.

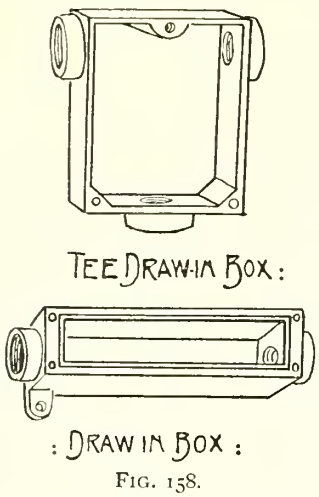


Fig. 158.

At A, Fig. 159, is shown the ordinary type of junction box, while at B the *knock-out* type is shown. The latter type is used where it is proposed to extend the wiring at some future time, and it will be seen from the figure that some of the holes in the sides of the box are stopped up with thin discs of metal C, which may be knocked out and the hole threaded for the insertion of a tube.

When the cables are drawn into sections of the circuit the method is as follows :—One length of conduit is fixed and the whole of the cable is drawn through it by means of strings or wires inserted in the tube before fixing. The cable is then drawn through the next length of tubing, and the tube is then fixed in position ; and this is repeated until the whole system is complete.

The conduit is fixed to the walls by means of staple or metal straps, and it may be exposed where appearance is of no object, or concealed beneath the plaster when it is desirable to hide it. In the larger sizes of conduit, chases have to be cut in the brickwork to keep them below the surface of the plaster face.

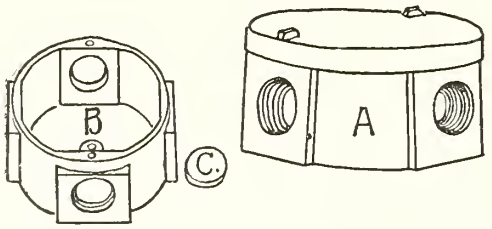


Fig. 159.

Ceiling Roses and Switch Boxes.—Special steel boxes are made for the reception of ceiling roses, switches, and other fittings. Fig. 160 illustrates two patterns of ceiling rose boxes, and Fig. 161 shows two patterns of switch boxes. All these fittings form suitable openings from which to draw in the cables. The covers of fitting boxes are of two kinds : one is screwed in by means of screws, while the other has a thread cut upon it which screws on to a corresponding thread on the base of the box.

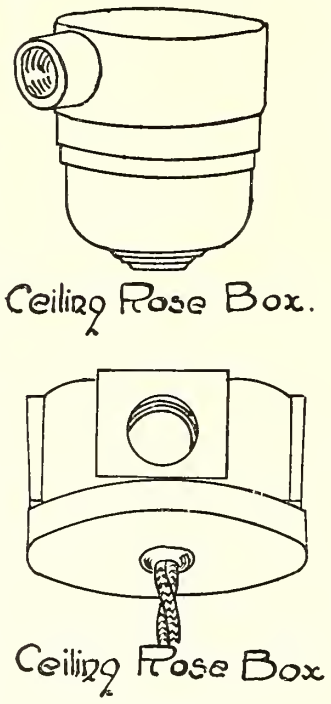


Fig. 160.

Water-tight Fitting Boxes are made for use in very

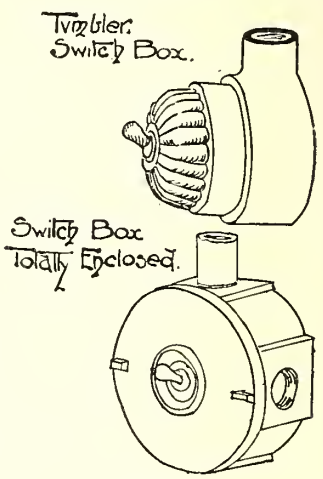


Fig. 161.

damp situations, of which Fig. 162 is an example. Fittings for conduit systems may be obtained to suit all possible requirements.

Distribution Boxes.—The fuses in a conduit system are usually grouped together, and enclosed in a special box called a distribution box, of the type shown in Fig. 163. These are made with any number of entrance holes to suit all possible conditions.

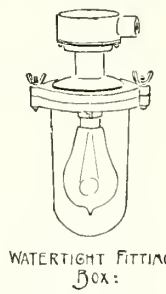


Fig. 162.

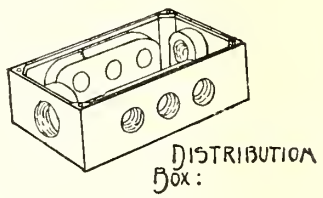


Fig. 163.

CHAPTER XIX

ELECTRICAL ACCESSORIES, FIXING AND CONNECTING

(*Contributed by H. Y. Margary*)

The principal accessories to electric-lighting installations, such as lamps, fuses, and switches, have been already mentioned in the chapter upon the arrangement of wires in a building, but it is necessary that they should now be more fully described.

Lamps.—There are two forms of electric lamp in general use; namely, the Incandescent lamp and the Arc lamp. Among the incandescent lamp group is the more modern Nernst lamp, whose filament requires heating by some exterior means before it glows or "incandesces," and the most recent "Osmium" and "Tantalum" lamps, whose efficiencies of candle-power per unit of electrical power consumed are said to be higher than those obtained by carbon filament lamps.

Incandescent lamps consist essentially of a thin filament of carbon contained within an exhausted glass globe. Various patterns of lamps are manufactured, designed for various pressures and candle-powers, but all on the same principles.

Lamps will usually burn for about 1000 hours if they are of good quality, but if of inferior quality their candle-power will drop, while the power required to light them will increase per c.p. so considerably that it does not pay to use them after the first 700 to 800 hours. Thus an Ediswan or other good make of lamp, of the 16 c.p. type, will emit 17 c.p. for the greater part of its life, and consume electrical energy at the rate of about 4 watts per c.p.; while a lamp of inferior quality will rarely emit as much as 15 c.p. when new, which c.p. will often drop as low as 8, with a consumption of energy starting at 4 watts per c.p. and rising to about 6.5 within the first 600 to 700 hours. Although good incandescent lamps consume energy at the rate of 4 watts per c.p., or 32 watts per 8 c.p., 64 watts per 16 c.p., and 128 watts per 32 c.p., it is usual, for the sake of simplicity, to calculate the size of the cables for such lamps at the rate of 30, 60, and 120 watts respectively.

The ends of the filament are connected to platinum wires, which are fused into glass supports. The ends of the platinum wires are connected to brass studs contained within the brass collar. Two brass pins project from the collar for fixing the lamps to the lamp holders.

Lamps are also made with frosted opal or tinted globes, or with one side of the globe silvered to act as a reflector. The actual light emitted from the filament of a lamp is absorbed by the globes to the extent shown in the following table:—

Clear glass absorbs	.	.	10 per cent.
Ground ,,	.	.	30 to 50 ,,
Opal ,,	.	.	50 to 60 ,,

Arc Lamps.—If two pieces of carbon be connected to the two poles of an electric circuit, and the points of the carbons be touched together and slowly drawn apart, a spark of great intensity is formed between them. A contrivance for mechanically performing the operation of touching the carbon points and drawing them apart again forms the essential portion of an arc lamp.

Fig. 164 shows diagrammatically the general arrangement of the mechanism of an arc lamp of the "enclosed" or long-burning type. The whole arrangement is suspended from a porcelain insulator A. The current is fed through the terminal B, B, insulated from the rest of the mechanism. The positive wire leads through the coil E to the split tube D, which holds the carbon G, and is so constructed that it can slide up and down in the tube C. The negative wire is connected to the lower carbon rod H through the support S. The lower carbon is clamped in position by the screw T. The carbons are adjusted so that they touch one another, and when the current is switched on the core E becomes magnetised and attracts the iron cone F, which pulls down the arm K which is pivoted to the tube C, so that the arm L and the clutch M are drawn upwards. The clutch M grips the carbon G, and draws it away from the carbon H, and so the arc is established. To prevent the coil from moving the core too suddenly, a contrivance known as a dash-pot is used, the action of which is as follows:—When F is drawn downwards, N and O are drawn upwards; O is a piston fitting closely into the cylinder P. The air can only enter slowly into the space beneath O, so that O can only move slowly, and thus checks any sudden jar. The mechanism is mounted upon a plate Q, which also serves the purpose of a reflector and a holder for the globe R. Arc lamps are usually connected up two or more in series, with a resistance, which has the effect of steadying the arc. The lamp shown must be considered as diagrammatic only, but is based upon modern practice as regards the enclosed

arc lamp, which has now practically taken the place of the older "open type" arc lamp. The only exception to this practice is the well-known Foster lamp, in which neither coil nor dash pot is used; but in which the formation and maintenance of the arc is for the purpose of this work substantially the same.

The Nernst lamp is a form of incandescent lamp, the filament or "glower," as it is technically termed, being

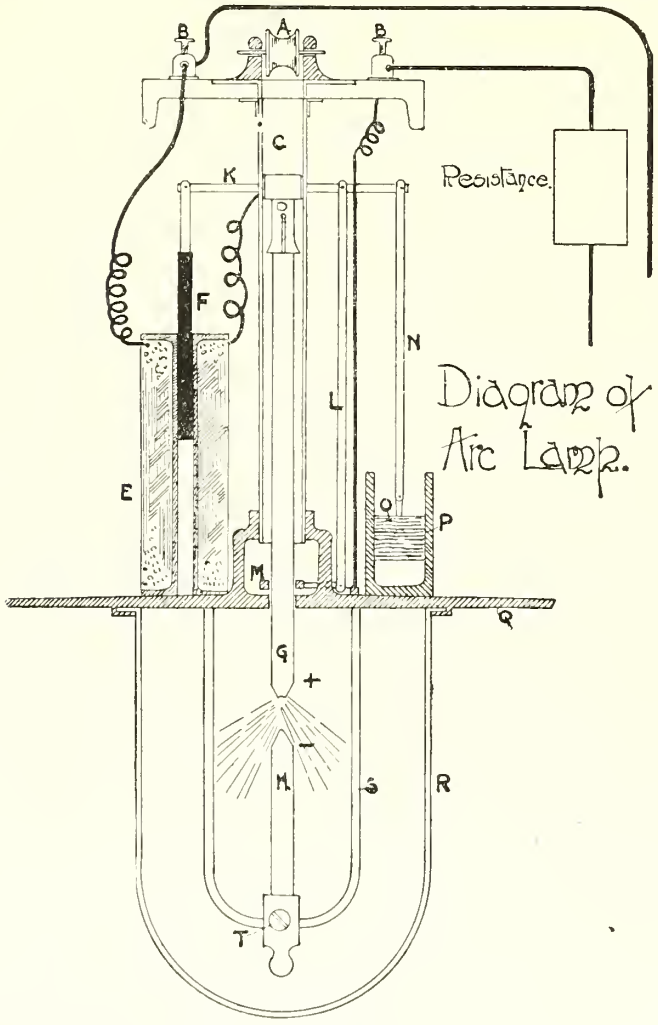


Fig. 164.

composed of a thin rod of china-like material containing a large percentage of some alkaline earth, which has the property of glowing with an intense whiteness when heated. This form of filament will not conduct an electric current until its temperature has been raised to a bright redness. The lamp must therefore be fitted with an arrangement for heating the glower until it is capable of conducting a current.

Fig. 164A shows the various parts of a Nernst lamp. A is a china fitting for connecting to an ordinary bayonet socket. Inside A is fixed a small electromagnet B for electrically switching the current from the heating arrangement D to the glower E. The glower and heater are mounted upon a china base F, which is connected to the rest of the mechanism by slipping the open tubes G over the split rods. The heater is composed of a zigzag rod of china, with a spiral of fine platinum wire bedded in its surface. K is a resistance, composed of fine iron wire spirals contained within an exhausted glass bulb, and connected to the two metal plates L, L, which slide between two spring clips M, M. The dotted lines represent the resistance bulb in position. The mechanism of the lamp is protected by means of the cover N, which screws on to the metal thread at O. P shows the glass globe broken away.

The drawing in the left-hand top corner of the figure shows diagrammatically the manner in which the lamp is connected up. The current enters at the positive terminal, along the contact spring curvature *a*, through the heater *b* and back to the negative terminal. The glower *c*, which is actually very close to the heater, becomes heated, and when at red heat the current finds an easier passage through the glower than through the

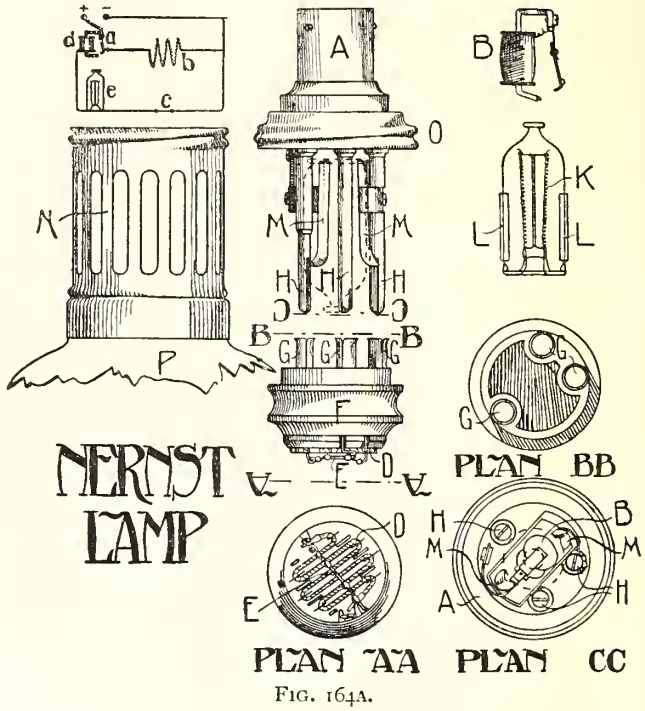


Fig. 164A.

heater, with the result that the current passes through the electromagnet *d*, through the resistance *e*, through the glower *f*, and back to the negative terminal. The current, on passing round the electromagnet, energises its core, drawing the armature towards it, and so disconnecting the heater.

Lamp Holders. — The fittings used for connecting lamps to a circuit are called lamp holders, the general types of which are illustrated at A and B, Fig. 165,—A being used for pendants and B for lights attached to walls or ceilings. This latter type is termed the batten holder.

The various portions of a pendant lamp holder are shown at C. The porcelain interior is inserted in the

socket, and the bayonet points are kept in a definite position relatively to the hooks or bayonet sockets O by means of the grooves G, G, which slip over the projections P, P. The cap S is placed over the porcelain interior, and is held there by means of the screw ring R, which is slipped up from the bottom of the socket and catches the flange F. When a shade is used the portion of the socket marked T has a thread worked upon it when the

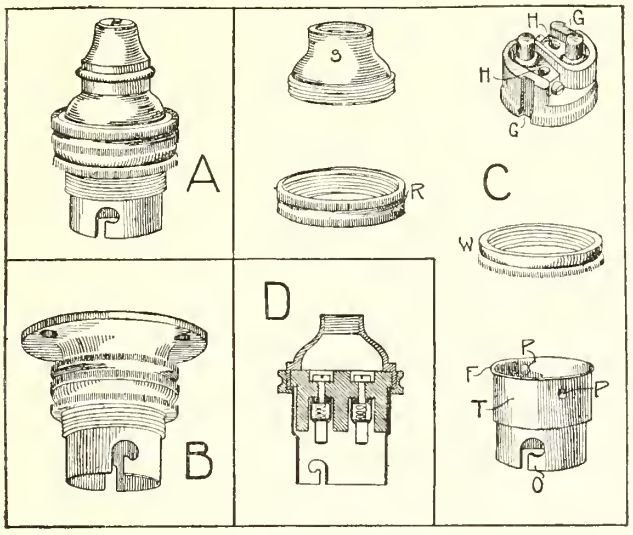


Fig. 165.

shade is placed in position, and a shade ring W is screwed up from beneath it.

The lamp is connected by pushing the two pins on the collar up the slots on either side of the socket and twisting the lamp, so that the pins catch on the hooks O, where they remain owing to the downward pressure of the springs in the contacts (see D, Fig. 165).

The wires are connected by stripping off the insulation at the ends and placing them in the holes H, H, where they are fixed by the two screws. The contacts press against the two brass studs in the lamp collar.

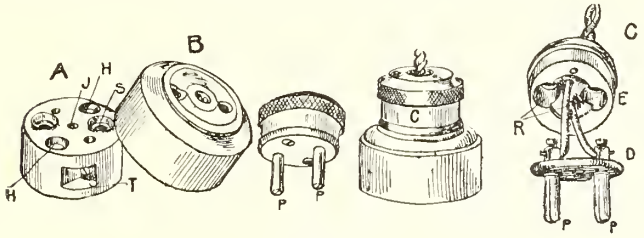


Fig. 166.

Wall Sockets and Plugs are contrivances used for connecting up table or standard lamps, and are of three kinds—the two-pin, bayonet socket, and concentric.

Two-pin Sockets consist of a block of porcelain A, Fig. 166, containing terminals T for fixing the leads, and a porcelain cover B. The terminals are made with long brass split sockets, as shown at S. The block A is fixed to the wire casing, or to the skirting, to wood plugs or fixing blocks by means of screws through the holes H. The cover is fixed by means of a screw passing through the hole in the centre, and through the hole J in the block A. The plug consists of two split pins P, P, fixed to an ebonite disc, which is attached to a porcelain cover by means of two screws. The flexible wires are fixed to terminals as shown, and are gripped firmly by the little ridges R formed on the inside of the cover. No switch is used with wall plugs of this form, as it is not easy to short-circuit them, the small brass sockets being well protected by porcelain. The act of placing the plug into the socket completes the circuits through the lamp attached to the plug.

Bayonet Sockets are usually made of batten lamp holders with a brass or porcelain cover, as shown in Fig. 167. The plugs are similar to lamp collars with an

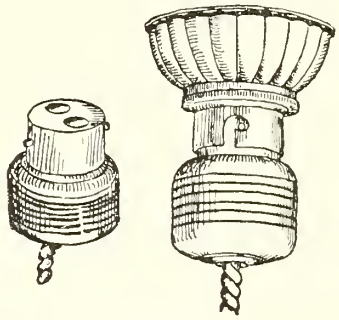


Fig. 167.

insulated handle instead of a glass bulb, and are inserted in the same way as lamps. A switch should be used in connection with these sockets, as the bayonets are not well enough protected to prevent a short circuit.

Fig. 168 shows the concentric type of wall plug and socket. The method of connecting this fitting is shown in the view of the interior. One wire is connected to the terminal T, and the current passes from the terminal through the fuse F to the ring R. The other wire is connected to the terminal S, which is fixed to a metal plate extending to the centre of the

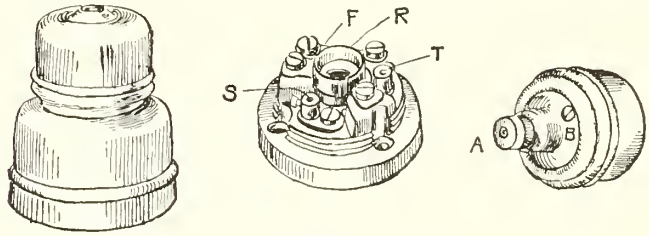


Fig. 168.

socket. A porcelain case protects the terminals from short circuits. The flexible wires of the plug are connected to the two pieces of brass A and B, and electric contact is made with the socket by the pressure of A upon the brass pin at the centre of the socket, and the pressure of B upon the ring R.

Wall plugs are made in various sizes to carry from 5 to 20 ampères.

Most Fire Insurance Offices prohibit the use of wall

plugs with fuses in them, because they involve a certain risk from fire, as they are usually fitted to skirtings or other convenient woodwork.

Adapters.— These are used for connecting table lamps or other fittings to the nearest lamp holder. Their construction is precisely the same as that of the plugs used with bayonet wall sockets. Fig. 167 shows a sketch of an adapter.

Ceiling Roses are contrivances for making an efficient connection between the cables and the flexible wires of pendant lights. Fig. 169 shows a very good pattern of ceiling rose. The two terminals are separated by a thick wall of porcelain, which obviates any danger of the formation of an arc. The peculiar formation of

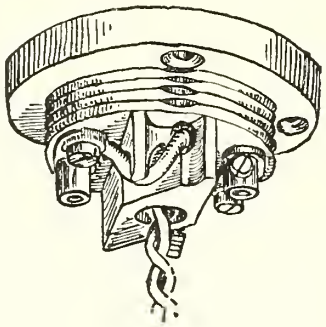


Fig. 169.

this wall is such that the flexible wires may be tightly gripped, so that no pull comes upon the ends attached to the terminals. Ceiling roses are usually fixed by screws to circular wooden roses set upon the casing, and the wooden roses are holed for the reception of the cables, and are fixed with screws to the ceilings joists or to wooden carriers nailed between the joists. Porcelain covers are screwed over the base to protect the terminals and to give a neat appearance.

Fuses.—It has already been stated that where a branch wire joins a larger wire, fuses must be used to ensure safety from fire. Fig. 170 shows one of the simplest types of fuse box, in which the fuse wire is mounted in a porcelain case. The base of the case has

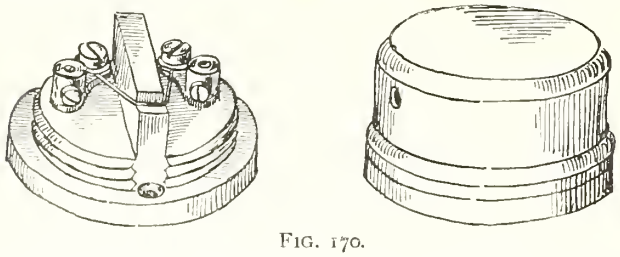


Fig. 170.

a wall of porcelain formed between the terminals to prevent "Arcing." The covers for these fuses are usually made of porcelain, with holes for ventilation purposes, so that the terminals may be kept as cool as possible, and that the air or the gases may escape when the fuse blows. This circular type of fuse is about 2 to $2\frac{1}{2}$ inches in diameter, and is suitable for circuits carrying from 5 to 10 ampères.

Fig. 171 shows a rather more elaborate type of fuse box, which is used for high voltage circuits. It possesses a very long break, varying from 2 to $3\frac{1}{2}$

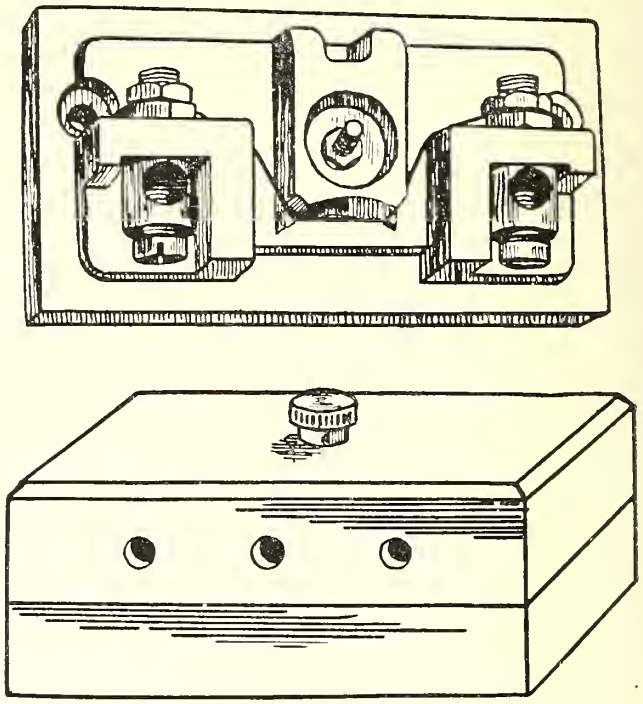


Fig. 171.

inches, so as to avoid all possibility of "arcing," and is further protected by means of porcelain walls. These are fixed in the same manner as the smaller circular fuse boxes.

The cover, which should be well provided with

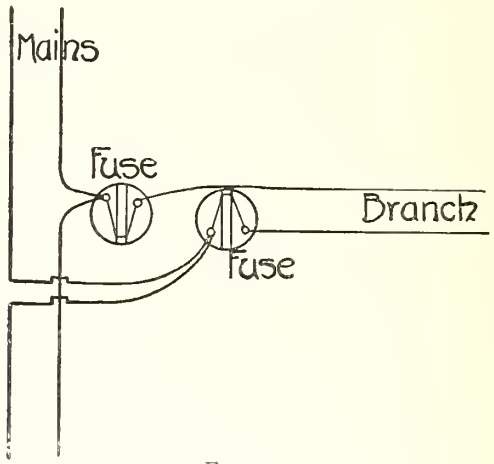


Fig. 172.

ventilation holes, is held in position by the thumb screw at its centre. These boxes are made from 3 to 7 inches long, and from $1\frac{1}{2}$ to 2 inches wide, with a projection of from $1\frac{1}{4}$ to 3 inches; and they will carry a current of from 10 to 100 ampères.

The method of connecting a branch to the mains, through fuses on each pole, is shown diagrammatically in Fig. 172. Fuse boxes of this description are useful

for connecting the branches of a tree system to the mains, since by looping out, as shown in Fig. 149, joints may be avoided, and the branches may with perfect safety be proportioned according to the current they have to carry.

Main Fuses.—The most useful form of fuse for connecting the house mains to a company's supply main is shown in Fig. 173. In this the fuse wire is fixed between two terminals contained within a porcelain

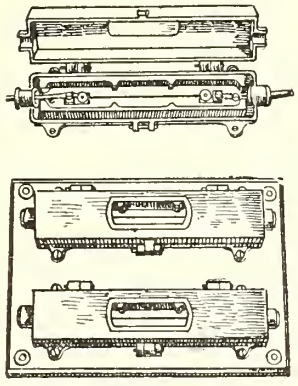


Fig. 173.

trough, which is protected by an iron case. The cables are carried through the insulators at the top and bottom of the iron case, and are connected to the fuse terminals by means of clamping screws. Two such fuse boxes are usually mounted side by side on a board with insulators at the corners, to form a double pole fuse, as shown in Fig. 173. This type of fuse box is designed for currents from 25 to 100 ampères. When large currents are to be carried, several strands of wire or strips of fuse metal are used

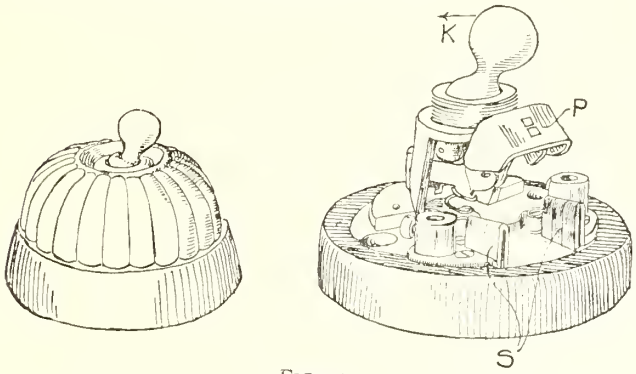


Fig. 174.

These main fuses are usually fixed by the supply company, and their property. It is nevertheless advisable to have a pair of consumer's main fuses, which should be fused to blow at slightly lower excess current than the company's fuses.

Switches.—The type of switch in common use for switching on incandescent lamps is shown in Fig. 174, and is known as the tumbler switch. By moving the knob K in the direction of the arrow the contact bridge P is brought downwards and makes contact between the springs S. The mechanism and terminals are mounted upon a block of china, and protected by either a brass or china cover screwed on to the thread beneath the knob K. When it is desirable that the switches should not

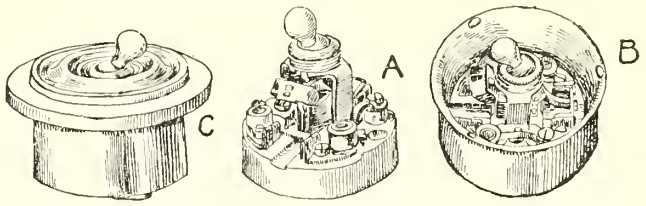


Fig. 175.

project as much as is shown in Fig. 174, a type of switch known as the "Flush switch" (Fig. 175) is used. In these the mechanism is mounted upon a block of china as shown at A, and attached to the bottom of a brass cup, as shown at B. These are let into the wall and

Fig. 176.

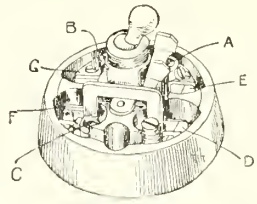


Fig. 177.

attached to wood plugs or fixing blocks, and a cover, such as is shown at C, is fixed over them. Flush switches may be made into ornamental features by the use of covers such as that shown in Fig. 176. For schools and asylums where it is desirable to prevent

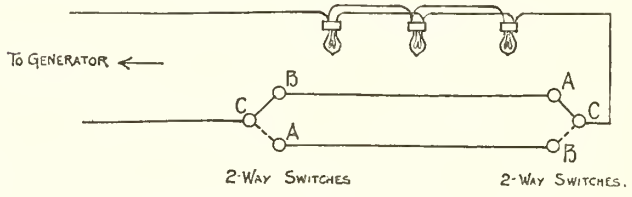


Diagram of Connections for 2-Way Switches.

Fig. 178.

the children or patients from tampering with the switches a form is used which can only be turned on with a special key.

Two-way Switches are used when it is desired to switch on a light from one point and to switch it off at another; thus it is usually desirable to switch on the lights on a staircase from the hall and to switch off the lights from one of the upper landings.

Fig. 177 shows an example of a 2-way switch which is of the tumbler type. It contains three

terminals, A, B, and C, and two pairs of contact springs, D, E, and F, G. The points C, D, and F are connected together, G and B are connected together, and so are A and E. In the present position of the switch con-

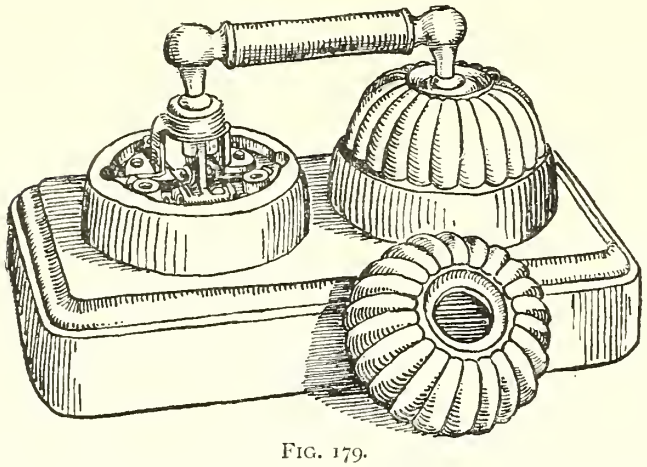


Fig. 179.

tact exists between C and B; while if the knob is pressed over the other way the contact is broken between C and B, and made between C and A. The method of connecting up two-way switches with a lamp circuit is shown in Fig. 178, the terminals of the

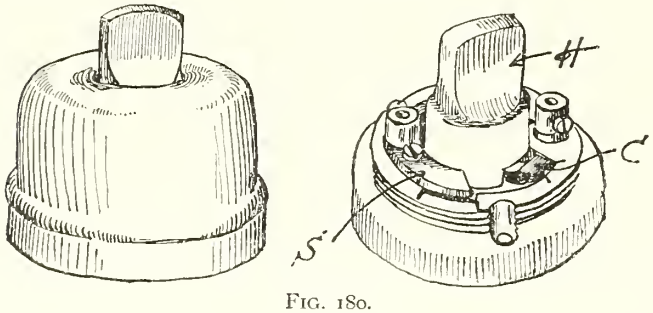


Fig. 180.

switches being represented by small circles which are lettered A, B, and C to correspond with the terminals in Fig. 177.

Double-pole Switches, for currents up to 20 ampères, may consist of two single-pole switches mounted on

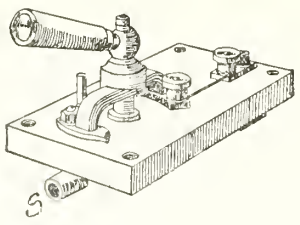


Fig. 181.

board, with the handles coupled together by means of a wooden bar, as shown in Fig. 179.

Turn Switches. Fig. 180 shows a type of switch known as a turn switch. By turning the handle H the laminated contact C is brought into contact with the under side of the brass strip S, and a similar contact is made on the other side of the handle. On account of the fact that contact is made or broken simultaneously on both sides of the switch the name "Double-break switch" has been applied to it.

Main Switches are of three general types, and are classified according to the nature of the contact they make. These are the *Brush-Contact* switch, the *Spring-Contact* switch and the *Knife-Contact* switch.

One pattern of a single-pole brush-contact switch

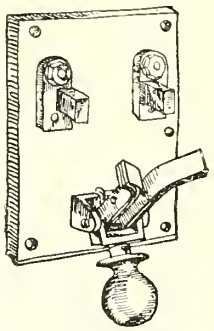


Fig. 182.

with a fuse attached is shown in Fig. 181. Two of these are often mounted together to form a double-pole switch.

A switch of the spring-contact type is shown in Fig. 182.

The knife-contact type of switch is shown in the *Change-over Switch* illustrated in Fig. 183.

Change-over Switches are used when electricity is obtained from two sources of supply, such as from a private plant and from a supply company's mains. They are sometimes used as a safeguard against a

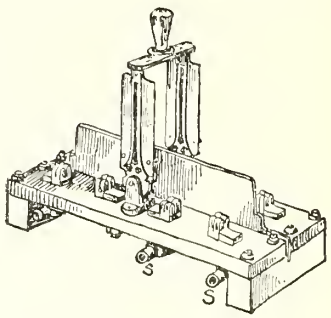


Fig. 183.

breakdown of the private plant, or when electricity is taken for some part of the day from a private plant and for the rest of the day from the local supply company.

The cables are connected to main switches by baring the copper conductors at their ends and sweating them into sockets connected with the contacts.

Distribution Boards may consist of a number of fuses mounted on a slate base and connected to the omnibus bars, in which case they are called *Distribution Fuse Boards*; or they may consist of a number of fuses and switches, when they are called *Distribution Switch and Fuse Boards.*

Distribution Fuse Boards.—The simplest form of distribution fuse board is shown in Fig. 185, and consists of two bus bars and a number of clamping terminals, attached to an enamelled slate base and enclosed in a teak case. To prevent the chance of an arc forming between the bus bars a projecting fillet

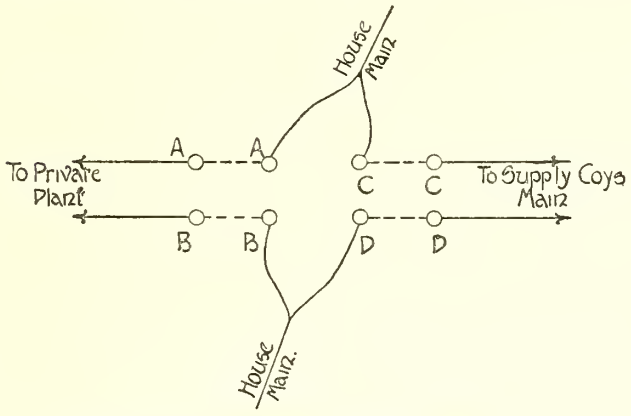


Diagram of Change-over Switch.

Fig. 184.

of slate is fixed to the base between them. The mains are connected at the back of the board to the terminals M, M by clamping, or by sweating the ends into sockets. The fuse wires are clamped between corresponding terminals such as T, T, and the cables for the minor circuits are clamped to corresponding terminals,

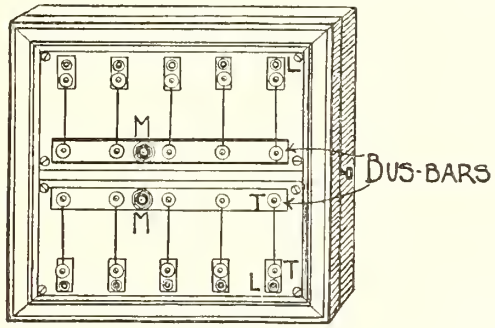


Fig. 185.

such as L, L, at the top and bottom of the fuse board. A very good type of distribution fuse board is shown in Fig. 186, where the fuse wires are carried on porcelain bridges of any of the patterns A, B, or C. These bridges are supported by means of spring clips attached to porcelain blocks on the base of the board. The main cables are connected to this type of board by clamping or sweating, while the minor circuits are connected to terminals at one end of each bridge, similar to those used in switches and ceiling roses.

Distributing Fuse and Switch Boards.—An example of this type of distributing board, designed for regulating three points of light, is shown in Fig. 187. The switches are not always enclosed within cases, but

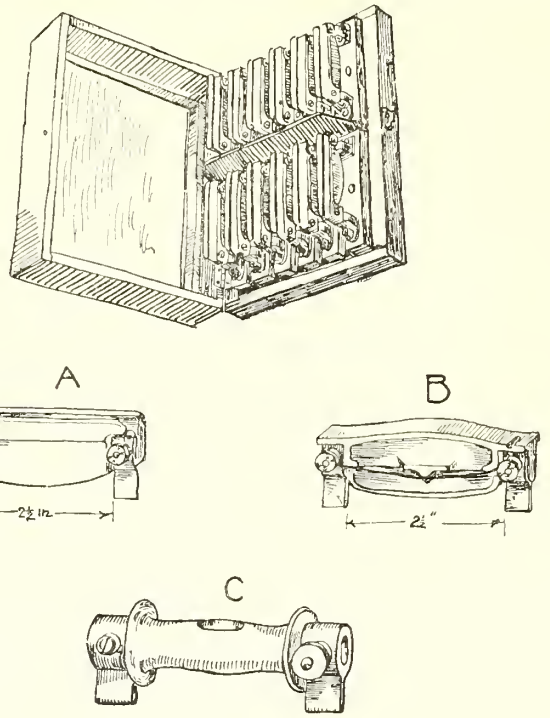


Fig. 186.

the fuses must always be enclosed to prevent the molten fuse metal setting fire to anything when it "blows."

It will be noticed that on all the distribution boards

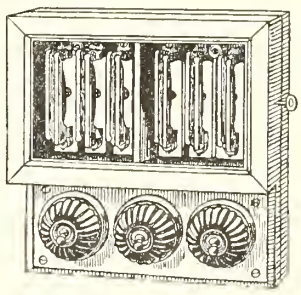


Fig. 187.

illustrated fuses are provided to each pole of the minor circuits; but they may be obtained with single-pole fuses only, and also with double-pole switches.

The cases used for enclosing distribution boards are usually made of teak, as this wood is very fire-resisting; iron cases can also be obtained.

CHAPTER XX

PRIVATE INSTALLATIONS

(*Contributed by H. Y. Margary*)

An electric lighting installation consists essentially of a dynamo with some form of engine to drive it, and all necessary wire, lamps, and fittings. Many circumstances govern the choice of engine and dynamo which are quite beyond the province of an architect or builder. The factors with which such are concerned are the prime cost of plant, the cost of upkeep, and the efficiency. The most economical power for driving a dynamo is water, where available. Steam engines and turbines, and coal gas and producer gas engines are used, while high-speed petrol motors, coupled directly to the dynamo, have been recently introduced. The design of the dynamo must of necessity depend upon the nature of the power employed to drive it. In small installations it is usually desirable to have the engine working for part of the day only, so that some means of storing the electricity must be provided. For this purpose secondary batteries or accumulators are employed.

Batteries are of two kinds, primary and secondary. Primary batteries are collections of cells such as that described in Chapter XIV., and are used for generating currents. They are of little use practically, except for operating bells and telephones, for experimental purposes, or for testing. Secondary batteries are collections of secondary cells, and are used for the purpose of storing electricity. These are of great use practically, as a battery of cells occupying little space can be used for storing sufficient electricity for driving many lamps or motors.

Secondary Cells or "Accumulators" consist essentially of two lead plates immersed in dilute sulphuric acid, and provided with suitable terminals for connecting the ends of an external circuit to the plates.

In practice accumulator cells are made up with a large number of plates, the capacity increasing in direct proportion to the number of plates. The capacity of a cell may also be increased by increasing the size of its plates, but as this tends to weaken the plate it is preferable to increase the number. Plates usually have a superficial area of one square foot.

The plates are supported within a glass box containing dilute sulphuric acid, so that they are entirely immersed. When accumulators are subjected to hard wear, as in motor cars or yachts, the plates are contained within boxes of lead-lined teak. They should be as close together as possible, to reduce the internal resistance of the cell to a minimum, but care should be taken to avoid contact even by small particles becoming detached and lodging between them. The plates are usually separated by strips or rods of ebonite, glass, or glass tubing. Cells are also made in which the plates are separated by layers of thin porous material, and a number of plates are kept together by the pressure of elastic bands, specially prepared to resist the action of the acid. Such cells are made up in sections of several plates and separators, and cells of any capacity may be built up by placing a number of these sections together. The plates may rest upon blocks or strips of wood placed at the bottom of the glass cell, or may be suspended from their edges. Care should be taken not to concentrate the weight of the plates on too small an area of the bottom of the glass cell, otherwise the glass is liable to crack and the acid to be spilt. Sometimes glass ribs are formed upon the bottom of the glass cells upon which the plates are rested. The method of suspending the plates is usually considered more satisfactory, as any small particles of plate which drop off may then accumulate in the space beneath the plates, with very little chance of forming a connection between them.

When cells are received from the makers the plates are usually made up in sections ready for placing in the cells. These should be handled carefully to avoid bending or cracking, and all dust should be removed by the use of a pair of bellows or a soft brush. Any piece of packing material which may have found its way between the plates should be carefully removed by means of a thin slip of wood. The separators should be examined, and any that may have got out of place should be adjusted and any that are broken should be replaced.

Connecting up Cells.—Each cell, no matter what its size may be, gives an E.M.F. of 2.2 volts when fully charged, and this pressure continually drops while the cell is being discharged. If the discharge goes on too long the plates are seriously affected, so when the E.M.F. of the cell has dropped to a certain limit the cell should be recharged. This limit is fixed by the makers, and is usually 1.9 volt; although some makers permit their cells to be discharged until their E.M.F. has dropped to 1.8 volt.

If, therefore, a battery of accumulators is required

to give a pressure of 100 volts, the number of cells required will be $\frac{100}{1.9} = 53$. To obtain the combined E.M.F. of the cells they must be connected up *in series*—that is, the positive pole of each cell must be connected to the negative pole of the next cell, and so on.

All the plates have lugs of lead cast on to them, and all the positive plates and all the negative plates are connected together by casting stout lead bars on to these lugs. The lugs of one cell are connected to the lugs of the adjacent cells. Clamped connections should be carefully and heavily varnished, to protect them from the acid fumes arising from the cell. The method of burning together is usually employed when the cells are large, but it lacks the convenience of clamping, which enables a cell to be readily removed for repairs.

Charging Accumulators.—The maximum charging current is usually fixed by the makers, and this should not be exceeded, otherwise the plates will be damaged and their life considerably reduced. It is usually the same as the maximum discharging current; and it is usual, except under special circumstance, to charge with the maximum current, so as to reduce the time required for charging to a minimum. The E.M.F. required for charging each cell is 2.5 volts, so that a considerable loss of pressure takes place between the charging and discharging current,—so much so that accumulators would not be used at all were it not for the numerous compensating advantages which they possess.

The dynamo for charging the cells should be carefully tested, to see whether the maximum current is in accordance with that specified by the makers of the cells.

The acid should not be placed in the cells until all is absolutely ready for the initial charging. It should be of a particular density specified by the makers of the cell, usually about 1.21, pure distilled water alone being used for diluting the strong acid as received from the manufacturers. When all is ready the charging current should be switched on to the cells, the positive terminal of the dynamo being connected to the positive terminal of the battery, and the negative to the negative.

In charging the positive plates turn the colour of wet chocolate, owing to the formation of peroxide of lead, and the negative plates to the colour of slate, owing to the formation of a spongy surface of lead, the colour becoming deeper as the charge increases. The extent to which they are charged may be roughly gauged by the appearance of the plates. As the charging continues the density of the acid decreases, and when fully charged this should not be less than 1.15. The charging continues until it reaches the value specified by the makers, which with a new set of cells may take twenty-four hours or more. Another indication that the cells are fully charged is the appearance of "boiling" which takes place. This is not due to heat developed within the cell, but is caused by the evolution of gas. On its appearance the charging should be discontinued, when the battery, if the cells are in good condition, will give an E.M.F. which, when divided by the number of cells, will be equal to 2.2 volts.

The boiling of the electrolyte, as the acid is sometimes called, causes a spray to be thrown up from the surface of the acid, which will damage any insulating material or metal in the immediate vicinity. To prevent this spray from becoming wafted about, the cells are covered with sheets of glass, tilted so that the spray that collects thereon may run down and drip back into the cell. If this method is employed, care must be taken that the glass does not touch the plates, otherwise the film moisture upon the glass short-circuits the cell. Another method is to fill the cell with acid to a level half an inch higher than that actually required; then place a peg of wood in one corner of the cell and pour melted paraffin wax or other easily fusible compound upon the surface of the acid. When the wax has cooled the peg in the corner is removed carefully, and the level of the acid is reduced by means of a glass syringe inserted in the hole left by the peg. This method creates rather a nuisance when a cell has to be taken to pieces for repairs. Perhaps the best method is to cover the surface of the acid with crumbled cork or little hollow balls of glass. When cork is used it should be prepared by boiling in paraffin wax so that the acid cannot char it.

Accumulator House.—As acid fumes pervade all the space in the vicinity of accumulators, these should be set up in a house or shed well isolated from the dynamo, which is easily affected by the corrosion of the metal parts and the consequent deterioration of the insulation. The house should be preferably lined with glazed bricks built in cement mortar to withstand the acid fumes, and should be well lit from a louvered skylight in the roof.

The floor should be of concrete, asphalt, or some impervious material which is not affected by acid, and laid to a fall towards a gully to facilitate washing down.

Strong racks of pitch pine or teak well planed and shellac varnished should be formed to carry the cells. Where space is lacking the cells may be supported in two tiers, but it is better that the accumulator house be long and narrow, so that the cells may be arranged in one tier down the centre, that they may be thoroughly examined from each side, and so that any cell may be easily cut out for repairs. The racks, which should be composed of stout horizontal members braced together at intervals, should be supported at a height of about 30 inches from the floor. The supports should be of glazed brick, as wood becomes saturated with water owing to the constant flushing of the floor.

CHAPTER XXI

ELECTRIC LIGHTING REGULATIONS

(*Contributed by H. Y. Margary*)

Of the many regulations relating to electric lighting, those most immediately important are the rules laid down by the Fire Offices. Next in importance are those of the local Supply Company, or whoever is responsible for the supply of the current.

The Board of Trade rules, based upon the Electric Lighting Acts of 1882 and 1888, rarely affect the consumer or his adviser when the supply is obtained from the street mains: they apply principally to the "undertakers,"—that is to say, the Supply Company—and when the rules of the Supply Company and of the Fire Offices have been adhered to it may be considered that there will be no difficulty with the Board of Trade.

Board of Trade Regulations.—A copy of these, relating to the Electric Lighting Acts, 1882 and 1888, may be obtained through any bookseller for 2d. Their twofold aim is "for securing the safety of the public" and "for securing a proper and sufficient supply of electric energy." The expression pressure means the difference of electrical potential between any two conductors through which a supply of energy is given, or between any part of either conductor and the earth; and, subject to the variations allowed by No. B3 of these Regulations:—

"(*a*) Where the conditions of the supply are such that the pressure at any pair of consumer's terminals does not exceed 250 volts, the supply shall be deemed a low-pressure supply;

"(*b*) Where the conditions of the supply are such that the pressure exceeds 250 volts but does not exceed 650 volts, the supply shall be deemed a medium pressure;

"(*c*) Where the conditions of the supply are such that the pressure exceeds 650 volts but does not exceed 3000 volts, the supply shall be deemed a high-pressure supply; and

"(*d*) Where the conditions of the supply are such that the pressure exceeds 3000 volts, the supply shall be deemed an extra high-pressure supply."

With reference to the foregoing definitions of various different pressures the first or low-pressure is the one principally to be dealt with in ordinary lighting schemes.

The medium pressure (definition *b*) will enter into a scheme including power, as, for instance, in factories, theatres, hotels, and such buildings. The high pressures and extra high pressures (definitions *c* and *d*) will rarely have to be considered.

It will be sufficient to deal only with the first part of the aim of these rules, namely, "for securing the safety of the public."

It may be noted here that most theatres, hotels, and large buildings are now fitted with power for passenger lifts; and it is the general practice to supply power at double the voltage of the lighting circuit. Further than this, the use of arc lamps burning in series on power circuits is a practice that rarely obtains beyond street-lighting schemes, which are not within the scope of the present work.

There is an important regulation relating to the three-wire system of distribution which is as follows:—

"When the pressure between the outer conductors of a three-wire system exceeds 250 volts, and the three wires of the system or two pairs are brought into a consumer's premises, the supply shall be given to two pairs of terminals, arranged in such a manner that there shall be no danger of any shock, and the wiring from those terminals shall be kept distinct."

Another regulation is important, as indicating the kind of test to which the electrical contractor's work will be subjected:—

"Every low-pressure and medium-pressure main shall be tested for insulation after having been placed in position, and before it is used for the purposes of supply, the testing pressure being the maximum pressure to which it is intended to be subjected in use, and in any case at least 200 volts, and the undertakers shall duly record the results of the test of each main or section of a main."

Another regulation, though formidable at first sight, is considerably modified by the last clause, as practically every system of supply consists of the three-wire system in which the central conductor is earthed everywhere.

"The insulation of every complete circuit used for the supply of energy, including all machinery, apparatus, and devices forming part of, or in connection with, that circuit, shall be so maintained that the leakage current shall not, under any conditions, exceed one-thousandth part of the maximum supply current; and suitable means shall be provided for the indication and localisation of leakage. Every leakage shall be remedied without delay.

"Every such circuit shall be tested for insulation at least once in every week, and the undertakers shall duly record the results of the testings.

"Provided that where the Board of Trade have approved of any part of any electric circuit being connected with earth, the provisions of this regulation shall not apply to that circuit so long as the connection with earth exists."

"Where any electric line crosses, or is in proximity to, any metallic substance, special precautions shall be taken by the undertakers against the possibility of any electrical charging of the metallic substance from the line or from any metal conduit pipe, or casing enclosing the line."

Regulations 24 to 31 under the heading "Consumers Premises" are all important, and should be considered towards the end of the work of installing the work on consumers' premises.

"24. The undertakers shall be responsible for all electric lines, fittings, and apparatus belonging to them, or under their control, which may be upon a consumer's premises, being maintained in a safe condition, and in all respects fit for supplying energy.

"25. In delivering the energy to a consumer's terminals the undertakers shall exercise all due precautions so as to avoid risk of causing fire on the premises.

"26. A suitable safety fuse or other automatic circuit-breaker shall be inserted in each service line within a consumer's premises as close as possible to the point of entry, and contained within a suitable locked or sealed receptacle of fireproof construction, except in cases where the service line is protected by fuses in a street box; but no fuse or automatic circuit-breaker shall be inserted in the intermediate conductor of a three-wire system, where the pressure between the adjacent conductors exceeds 125 volts.

"27. All service lines and apparatus placed on a consumer's premises shall be highly insulated and thoroughly protected against injury to the insulation or access of moisture, and any metal forming part of the electric circuit shall not, unless efficiently connected with earth, be exposed so that it can be touched. All electric lines shall be so fixed and protected as to prevent the possibility of electrical discharge to any adjacent metallic substance."

Although these regulations refer principally to the duties of the "undertakers" who are responsible for the supply, it is as well that the consumer's adviser should be acquainted in some degree with their powers to demand alterations, while, at the same time, he may be able to forestall, by careful supervison, any little difficulties otherwise likely to arise.

When a proposed installation reaches a magnitude of, say, one hundred 16 candle-power lamps or the equivalent, say, from 7000 to 8000 watts per hour, it is necessary to consider whether the current should be purchased or generated on the premises.

The first point to consider is the probable consumption of current per annum. This will vary considerably with the purpose for which the premises are used; for instance, it is doubtful whether a mansion or dwelling-house would ever, under ordinary circumstances, be actually using more than one-half the 100 lamps at a time.

It would certainly not be advisable to assume that more than 50 lamps would be in use simultaneously. This would represent a consumption of, say, $3\frac{1}{2}$ units per hour, which is too small for profitable generation on the premises.

For business premises, factories, public institutions, or wherever the whole of the lamps are at work for 3 to 5 hours consecutively, the private plant would result in a considerable saving per annum.

As an instance, a draper's premises where the maximum output is 18 units per hour, the cost for current works out at $\frac{3}{4}$d. per unit per hour after paying for gas, oil, waste, repairs, part of porter's time, and 10 per cent. depreciation on the plant.

Modern tendency indicates the private plant whereever the average consumption reaches 8 or 10 units per hour for 350 hours per annum, but it sometimes occurs that the local Supply Company will make a special concession rather than lose a prospective consumer, and for this reason the authorities should be approached before definitely deciding on the private plant.

For larger outputs it would be better to install generating machinery, as it is unlikely that the supply authorities would be able to make any concession which would pay the consumer.

For generating up to 50 kilowatts (which in 1 hour would be 50 units), town gas may be used with fair economy; but beyond 50 kilowatts a gas production plant will result in the cheapest possible form of lighting.

When taking supply from the street mains it is sometimes possible to choose between "alternating" and "direct" or "continuous" current; and if the charge per unit be the same, it is very difficult to make a choice. If neither arc lamps nor motors are used, each supply is as good as the other; but at present and probably for some years to come motors will work more efficiently on direct or continuous current, while arc lamps specially designed for the purpose will be cheaper to run on the alternating supply.

There is one point, however, which should not be omitted: if either supply should be at a lower pressure it should be chosen, provided the use of motors or arcs do not decide the question.

Undertaker's Regulations for Wiring Work

These should be rigidly enforced, as all tend to the benefit of the consumer. The contractor aims to get his work done with a minimum of cost to himself, and is quite satisfied if he "gets through the test." As it

is quite possible to get a satisfactory test with faulty material on a dry building it will be seen that vigilance is necessary. On the other hand, damp in a new building will sometimes entirely spoil the test even with the best of work, by connecting the exposed parts of distribution boards, etc., to earth with a film or sweat of moisture; yet, unfortunately, damp does not of necessity expose the weak points of faulty workmanship. In a case of this sort it is necessary to get rid of the moisture from the parts affected in the best way possible with the means at hand.

It is advisable, before commencing work, to submit a sample of all fittings, cable, etc., to the undertaker's engineer. This course may save a great deal of trouble and loss of time and money, while the engineer of to-day will be found, without exception, courteous and willing to advise.

The following regulations have been compiled by Mr. H. Tomlinson-Lee, Chief Engineer of the Wimbledon Electricity Works, who has kindly permitted their publication. They may be taken as representative, and contain much that should be embodied in specifications of wiring for electric light.

The first clause is the usual "Declaration of pressure," beyond which a maximum variation of 4 per cent. only is allowed by B.O.T. regulations. This clause will vary according to locality, and in the case of direct current no "cycles" will be specified.

Pressure.—Alternating current will be supplied at a pressure of 220 volts, 50 cycles.

Main Switch.—A double-pole switch of approval construction must be supplied and fixed by the consumer in an accessible position, and as near as possible to the Council's fuse.

Meter Connections.—The necessary loops for the meter connections must be provided by the consumer in the position selected. A shunt wire of 1/18 gauge should also be left for the meter connections.

Completion.—All installations must be fully completed before they will be inspected and connected with the supply mains. No work of a temporary nature will be allowed, and no current will under any circumstances be turned on to any installation until the work is entirely finished.

Reinspection.—The Council's engineer will inspect and test each installation free of charge on completion, but if through defective work or other causes it is necessary to inspect again, a fee of 10s. 6d. will be charged for each and every subsequent test.

Fire Office Rules.—All work must be carried out to the satisfaction of the Fire Insurance Company, or if not insured to the rules issued by the Institution of Electrical Engineers, and to the approval of the Council's engineer.

Circuits.—All installations requiring more than 25 ampères may be required to be divided into separate circuits from the Council's meter or meters.

Switches.—No double-pole switch, except the main switch, shall control more than 10 ampères, and no single-pole switch more than fifteen 8 candle-power lamps or their equivalent.

All single-pole switches must be on the same pole.

Fuses.—Each circuit to be protected with a single-pole cut-out on both poles, and having a clear break of 1½ inch. Cut-outs should be of an improved high voltage type; those having small unventilated close-fitting covers are not approved, and no double-pole cut-outs of any pattern are to be used. Cut-outs to be arranged on distributing boards of non-combustible material. No cut-outs are to be fitted anywhere except on distributing boards, nor are fuses to be fitted in ceiling roses or wall plugs.

Wire.—The insulation resistance of all wires shall not be less than 600 megohms per statute mile. All wires greater than No. 16 must be stranded, and no wire smaller than No. 18 will be allowed.

The area of conductors should be so proportioned to their length that the drop in pressure does not exceed 2 volts with all lamps alight simultaneously, and they should be of such sufficient section that with the maximum current passing continuously there is no appreciable electrical heating.

Joints.—To be carefully made, soldered with resin flux only, and insulated with at least six layers of pure rubber strip, protected by waterproofed tape; no joints to be made in damp places or drawn into pipes. As far as practicable, joints should be avoided, leads being run back to terminals of fittings, etc.

Fittings.—To be carefully and efficiently insulated from gas and water pipes and from earth.

Wall plugs shall be preferably of the 2-pin type. Key socket holders where employed to be submitted for approval before being used.

Combination gas and electric fittings are greatly objected to, and if such are proposed they must first be effectively insulated from the gas supply pipe and approved by the Council's engineer.

Exposed Work.—No exposed metal carrying current will be allowed, and all switches, etc., must have insulated handles and covers, and must be so screened as to prevent risk of contact with charged metal by persons using the same.

Notices.—Forty-eight hours' notice must be given before any installation can be tested.

Insulation.—All installations will be tested at a pressure of 400 volts, and after one minute's electrification they must have an insulation resistance to earth of not less than 100 megohms, divided by the number of lamps installed. All fittings, switches, lamps, etc., must be fixed and connected when this test is made.

Outside Work.—All outside leads to arc lamps should be protected by lead sheathing, or else special thickly braided outer covering, thoroughly coated with good insulating enamel. Single conductors must never be enclosed in metal tubes, and single lead-covered wire will not be allowed.

Where incandescent lamps are used in outside brackets an insulating piece of ebonite or porcelain should be inserted between the holder and adjacent metal to guard against each leakage.

Arc Lamps.—Arc lamps should be provided with suitable inductive choking coils, or properly constructed resistance coils, and must be hung on insulators in all cases. Exposed terminals will not be allowed. They must be so constructed that the starting current is not more than 75 per cent. in excess of the normal working current.

Motors.—Proposals for use of these should in all cases be first submitted to the Council's engineer. The starting current is not to be more than 25 per cent. in excess of the maximum working current, and they must be provided with suitable resistance and starting switches so constructed that the starting and stopping of the motor shall not cause any disturbance of the lights on its own or neighbouring circuits. The terminals must be guarded against the possibility of accidental contact.

Motors, arc lamps, and special consuming devices must be controlled by double-pole switches, and be protected by an approved cut-out on each pole.

Radiators.—This term includes electric stoves, cooking and heating apparatus, hot plates, etc. These must be provided with a stand of incombustible material, and should be placed at least 18 inches clear of any woodwork or inflammable material. The terminals must be protected against accidental contact.

Special Hints.—Cut-outs, switches, etc., should be provided with proper covers, and be arranged where they will not be liable to knocks or other injury, as this causes heating, and possibly extinctions, or danger of fire.

Care should be exercised in arranging lamp bulbs in windows or show-cases so that they do not come in contact with flimsy paper, cotton, or similar goods, from which there might be a risk of fire originating. In crowded shop windows the lamps should be guarded by shades or other means.

Resistance coils, etc., should be specially inspected and guarded so that they will not endanger their surroundings if hot.

If these and similar precautions are adopted, and wiring work entrusted to thoroughly competent men, the electric light will be found to be much safer than any other illuminant.

The engineer will be pleased to advise in any case where special wiring may be required, such as cold stores, breweries, and damp buildings, drapery warehouses, wood-working shops, organ chambers, printing and bookbinding works, etc.

A few words upon the various systems of charging for current may not be entirely out of place.

There are four systems—the Flat Rate, Flat Rate with Rebate, Flat Rate with Sliding Scale, and the Maximum Demand System.

The first is the original method of charging a fixed sum per unit (maximum fixed at eightpence by Board of Trade) for any quantity.

The Rebate system provides a discount according to quantity beyond a minimum.

The Sliding Scale system charges full rate for a fixed minimum, but reduces the rate from that to another minimum beyond which the amount of current used is charged at a still lower rate, so that the total will be made up of three items where the consumption is large enough to take full advantage of this arrangement.

The maximum demand system regulates the charge according to the largest amount (or demand) of current taken at any one time during the quarter.

CHAPTER XXII

OIL GAS

(Contributed by H. Lut rell Godden)

Amongst the many modern improvements, both in effect produced and in economy of production, the use of gas obtained from light oils or spirits, both for lighting and heating purposes, cannot be passed over.

This is especially the case in dealing with country districts, where are found many isolated mansions and other private residences, and where coal gas or current for electric lighting are unobtainable unless from special producer plants erected for each individual case.

The idea of using oil or spirit, both on account of its initial cheapness and facility of transport, is not by any means new, but it is only within the last few years that practical results have been realised.

The general principles involved are the same in all systems, and may be stated as follows:—

The inflammable oils and spirits consist of various hydrocarbons and their derivatives. These, if heated to a sufficient temperature, will vaporise into gases, which, in combination with a sufficient proportion of oxygen supplied from the air or some other source, will burn with a more or less luminous flame.

Thus the results mainly depend on (1) temperature, and (2) supply of oxygen.

The production of gas from the heavier oils may here be disregarded, this being somewhat analogous in process and plant required to coal gas, and attention confined to that obtained from the lighter oils and spirits which are readily vaporised, such as petrol, benzol, turpentine, etc.

Petrol is generally used for the purpose, both on account of its cheapness and the low temperature at which it can be vaporised.

The process may be briefly described as Carburetting Air, and consists of passing air through a carburettor, in which it takes up a proportion of the vapour of the oil or spirit with which it comes in contact, forming an inflammable mixture of air and vapour.

It is obvious that, if the temperature required to vaporise the oil or spirit were above that of the atmosphere, the oil or spirit would condense and be deposited when the produced cooled down in passing through the service pipes. This has been, and still is, a cause of serious trouble in many forms of apparatus; but in a good carburettor the petrol is vaporised at a very low temperature, far below that of the surrounding atmosphere, and consequently the mixture of air and gas is stable, provided the components do not separate by gravity, which might happen if kept stored for any length of time. As, however, the plant is usually only working while gas is being consumed, the gas is always in motion from producer to burner, and trouble from this source avoided.

One of the chief difficulties that has been encountered lies in the fact that petrol itself is a mixture of various hydrocarbons of a series, some of which vaporise more readily than others, so that if the air is simply passed over or through the liquid spirit the lighter hydrocarbons are all taken away first, and the gas produced is too rich; while later on, when only the heavier and less readily vaporised spirit is left, the air does not take up a sufficient proportion, and the gas is too poor perhaps to burn at all, while a residue of oil or spirit remains unfit for the process and must be disposed of otherwise.

This difficulty led to the adoption of a "metrical" carburettor, by means of which only the quantity of petrol required to carburet a given volume of air was measured into the carburettor as that volume of air was passed through, and the whole was vaporised.

Again, the temperature of the carburettor must not be allowed to fall too low, or the spirit will cease to vaporise at all. Consequently the thermal units taken up in vaporisation must be replaced, and this is done by radiation from without, such as by placing the carburettor in a jacket of water, glycerine, or oil, which is kept in circulation.

The amount of power required to drive a plant of from 25 to 100 burners is very small, as a pressure of only 3 or 4 inches is quite sufficient, and this power is usually obtained by a weight or by a small water or hot-air motor.

The gas resulting is poorer in luminosity than coal gas, but gives a much higher flame temperature, and for lighting requires to be used with incandescent fittings, while for cooking or heating it gives an almost colourless and odourless clean flame.

The general faults to be found in most makes of petroleum gas plants are—(*a*) that the gas produced varies greatly in quality; or (*b*) that constant expert attention is required to obviate this.

The former (*a*) arises from the two chief difficulties previously mentioned not being satisfactorily overcome,

and consequently the richness of the gas varies considerably according to the temperature of the air, and is very marked between summer and winter, while the variation of specific gravity in the liquid spirit in the carburettor may cause similar trouble at any time.

In most plants an endeavour has been made to overcome these troubles by a regulator which can be set to vary the length of time during which the air is in contact with the spirit, but this method brings in the objection (*b*) of requiring constant and expert attention to adjust the regulator.

A third drawback still is sometimes apparent through the spirit partly condensing in the service pipes, due to the carburetting process being carried on at too high a temperature.

The ideal plant should produce a gas of constant quality under all conditions, should be automatic in working, so as to require no skilled attention, and be of extreme simplicity in all its parts.

It has been claimed of various designs that they have overcome the above difficulties, but only one, and that quite recently invented, approaches the ideal, that of Mons. Benoit de Laitte, of which a short description and sketch (Fig. 187A) are appended.

This plant consists of the usual parts—(1) a small reservoir R, containing about one pint of petrol, which feeds the carburettor; (2) the carburettor C itself; (3) a rotating air suction fan F, of special design; and (4) a small holder H, which also acts as a regulator.

The driving power is obtained in small plants by means of a weight W, on a wire rope, the rope be passed through a series of pulleys and wound on to a drum D.

This weight rotates the drum, which is geared to drive the air fan, and also the feed of spirit to the carburettor, which is on the metric principle, and takes in exactly the amount of spirit required to carburet the volume of air passing through the carburettor at the same time.

To prevent the temperature falling too low, the carburettor is placed in an antifreezing mixture of glycerine and salt, kept in constant circulation by the air fan which works in the same. This fan sucks in air from the open through the carburettor.

The gas thus made is delivered to the small holder, which is sealed with glycerine and, acting as a regulator, is set to a pressure of 4 inches, and is connected by a lever L to a band brake (B) acting on the driving drum, which stops the action entirely when no gas is passing or the full pressure is on, and retards or allows acceleration according to the quantity of gas being used. From the holder the gas is delivered to the main service pipe.

To avoid constant filling of the small reservoir, and to prevent danger, in accordance with the regulations for storing petrol, the bulk of it has to be kept not less than 16 feet from a building, and therefore the petrol tank is placed outside, and is connected to the reservoir by a small feed pipe and a gauge placed on the reservoir.

From this reservoir the petrol is fed in small quantities by a thimble (Fig. 188) at the end of a pipe, and this pipe is made to rise and fall, each time dipping up the thimble full of petrol and letting it run through

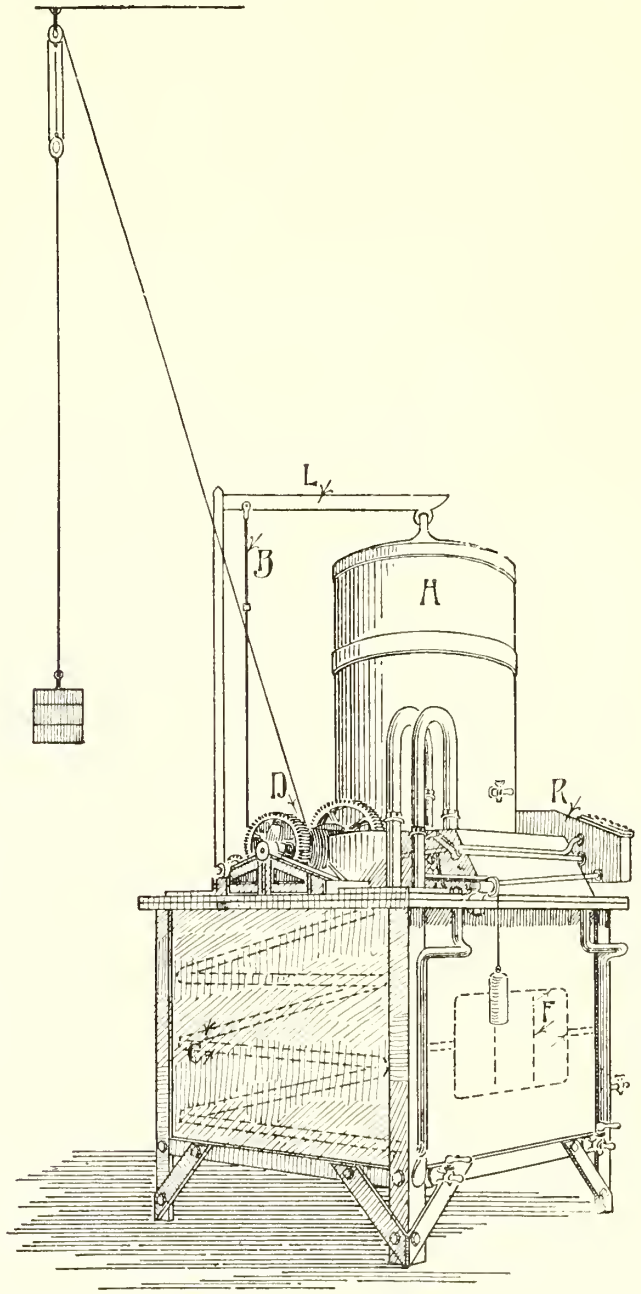


FIG. 187A.

the pipe to a small well over the carburettor, where a similar pipe and thimble, as shown in Fig. 188, transfers an exact amount of petrol to the carburettor. These thimbles and pipes are actuated by a paul and rachet action from the driving drum, and their movements are correlated to the action of the air fan

The carburettor is zigzag in form, and the air is sucked through in given volume. If necessary the air is first dried by being passed through or over calcium chloride.

This plant when put together is very compact, and can be covered up in a neat casing, taking up only a small amount of space, a 30-light plant measuring over all only 27 by 27 by 49 inches in height.

A paul and rachet allows the driving weight to be wound up with ease by hand without interrupting the action of the plant at any time. Practically this is all the attention required once it has been started to work, with the very occasional refilling of the outside petrol tank. Thus the labour to the household involved is not appreciably more than in ordinary coal-gas lighting. The effect of measuring a given amount of petrol to the carburettor ensures that the whole of the spirit is vaporised, so that there is no residue to be dealt with; and the resulting gas is practically constant in quality, no matter what the time of year or the temperature.

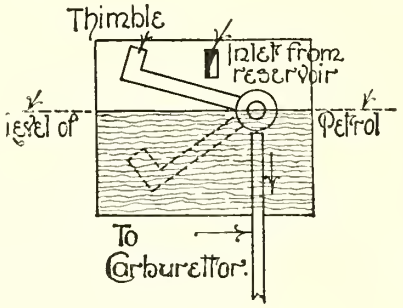


Fig. 188.

This apparatus has been used very successfully on the Continent even for lighting small towns and villages, which proves the permanent quality of the gas, and although quite new to this country it is meeting with a very large measure of popularity.

The general advantages of the use of petroleum gas are many, and far more than counterbalance any drawbacks.

In any system the necessary quantity of petrol required to carburet a given quantity of air varies somewhat with the specific gravity of the spirit used; but taking 0.680 spirit, such as is used for motor cars, one gallon will carburet from 850 to 1000 cubic feet of air.

This introduces the question of cost.

A 30-light plant will cost about £50, but for other sizes the price may be put at from 30s. to 25s. per burner, for the producer plants of most makes, to which must be added the cost of running the service pipes. Ordinary gas fittings are suitable, if these are not already laid in.

The whole is a very small capital outlay.

The absolute cost of producing gas depends on the price of petrol almost entirely. To-day this can be bought in bulk at certainly 1s. per gallon, and the cost of the gas would work out at about 1s. 6d. to 2s. at the utmost per 1000 cubic feet, after allowing for carriage, wages, etc., in the country,[1] which compares more than favourably with coal or acetylene gas or electric lighting in any locality.

The next point is that properly proportioned petroleum gas is less dangerous to use than coal gas in the event of a leakage. The mixture of inflammable vapour and air in the gas itself should be such as to ensure perfect combustion, so that should a leak occur the addition of more air, instead of creating an explosive mixture, as is the case with coal gas, simply dilutes it and renders it comparatively harmless. Nevertheless, a leak when detected by the smell—which by the way is nothing like so unpleasant as that of coal gas—should not be sought for with a naked light.

A further source of economy, due to the purity of this gas, is that incandescent mantles will not only last very much longer than with coal gas, but they will also retain their pristine brilliancy almost unimpaired throughout, as there is no carbonising action taking place. A mantle that has been burning on a coal-gas burner for some three weeks, and from which much of the lighting power had been lost, may be placed on a petroleum gas burner for one hour with the result that the mantle will be practically burnt clean again, and have almost entirely regained its original brilliancy, and retain it even when replaced on the coal-gas burner.

As regards the question of hygiene, which is a very important one, petroleum gas, on account of its purity and proportioning to give perfect combustion, does not contaminate the atmosphere of the room in which it is burnt to anything like the same extent as coal gas or even ordinary lamps. The products of combustion are almost entirely water, a small proportion of carbonic anhydride and free nitrogen from the air.

There are none of the poisonous products due to sulphur and other impurities which are found in coal gas, no blackening of ceilings or destruction of the contents of the room; neither is there any fear of corrosion in the service pipes and fittings.

The gas burns without smell, and is pre-eminently clean and innocuous in use, and therefore especially adapted for gas-cooking stoves.

All the principal insurance companies have set the seal of their approval on its use, provided an accepted make of producer plant is used, and several railway stations are installing this system of lighting.

[1] A 50-candle-power light costs about 0.1d. per hour.

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